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Effective Use of Information Systems for Emergency Management: a Representation Theory Perspective

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EFFECTIVE USE OF INFORMATION SYSTEMS FOR EMERGENCY MANAGEMENT: A REPRESENTATION THEORY PERSPECTIVE

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ABSTRACT

Effective Use Theory (EUT) has emerged as a promising native Information Systems (IS) theory to understand a central phenomenon of interest to the discipline: the effective use of information systems. While EUT is widely accepted in operational control and management control contexts, its validity in chaotic environments has yet to be demonstrated. To contribute to the research program in EUT, scholars called for contextualizing and assessing EUT in chaotic environment, such as emergencies or crises events. This research seeks to apply EUT to understand the effective use of emergency information systems (EMIS). Seeking a grand theory of effective use in EMIS helps the onset of a structured research program and the development of a cumulative research tradition. That fosters EMIS as a would-be reference discipline for cross-disciplinary scholarship in emergency management. Moreover, assessing EUT in the edge context of emergencies, contributes to theory development by problematizing on assumptions that scholars have been considering unproblematic.

CHAPTER 1
INTRODUCTION

During the last decade, the scholarship in information systems (IS) has seen a renewed interest in studying the system's use from a representation theory (RT) perspective (Burton-Jones & Grange, 2013). In particular, RT has informed the development of Effective Use Theory (EUT), which focuses on studying how systems can be used to attain intended goals (Burton-Jones & Grange, 2013). Central to that perspective is the understanding of an IS as a semantic system that users interact with to retrieve digital representations of a real-world domain (Burton-Jones, Recker, Indulska, Green, & Weber, 2017).

According to EUT, users attain *effective use* when they are able to leverage digital representations to take informed actions. This focus on studying IS systems *in-use* is what distinguishes the recent representation theory perspective (Burton-Jones & Volkoff, 2017; Burton-Jones & Grange, 2013; Burton-Jones et al., 2017), from the earlier representation theory perspective, which focused on the system *before-use* (Wand & Weber, 1995).

Nonetheless, a current limitation of representation theory is that it was primarily developed with operational control and management control contexts in mind, where "the real-world phenomena to be represented by an information system seem reasonably evident." (Burton-Jones et al., 2017, p. 17) Emergency management, the context of our research, instead, presents peculiar environmental stressors that EUT and RT research have substantially overlooked. In particular, EUT has yet to be assessed regarding other IS archetypal artifacts and their use in chaotic environments such as emergency (Burton-Jones et al., 2017). This dissertation addresses this theoretical gap through three essays.

The first essay, *A Literature Review of Emergency Management Research in Information Systems* is a review of the current scholarship in EMIS. The research presents the fragmented theoretical landscape characterizing EMIS literature, arguing that alternative theoretical perspectives should be explored which foster knowledge accumulation and disciplinarity.

The second essay, *Contextualizing Effective Use of Information Systems to Chaotic Environ-*

ments contextualizes RT in a chaotic environment (emergency response) to investigate the environmental stressors that threaten the theory's validity when acute time pressure and uncertainty characterize a system's use (Bonaretti & Piccoli, 2018b). Through the problematization of currently accepted assumptions in representation theory, we refine the notion of effective use as the time-dependent ability to *project* informed actions based on the system's representations. Discussing the ultimate goal of the system's use as consisting in *projecting* rather than *enacting* action is a nontrivial question in representation theory with major epistemological implication. While the theory currently adopts a *performative* perspective (Orlikowski, 2007) of effective use (*informed action*), we propose an *ostensive* (Latour, 1984) perspective that focus as system's use to increase *situational awareness*. This reconceptualization of effective use is empirically assessed in the last chapter of this dissertation.

The third essay, *Assessing Effective Use of Campus Emergency Alert Systems*, provides empirical support for a time-dependent measure of effective use contextualized to SMS alert systems. In particular, we propose a measure for the tri-dimensional conceptualization effective use Burton-Jones and Grange, 2013, which accounts for the time-dependent nature of effective use.

CHAPTER 2
A LITERATURE REVIEW OF EMERGENCY MANAGEMENT RESEARCH IN INFORMATION SYSTEMS

2.1 Introduction

2017 was a record year for disaster-related losses in the US, with an annual cost of more than $300bn and 362 casualties (NOAA 2017). The unprecedented disruptiveness and frequency of natural disasters highlighted the role of information technology (IT) in supporting emergency management information systems (EMIS), particularly during disaster response. EMIS are systems "used by organizations to assist in responding to a crisis or disaster situation" (Jennex, 2004, p. 85). In the 2013 World Disasters Report, the authors noted that "when disaster strikes, access to information is just as important as food and water" (IFRC, 2013, p. 73), which shows that the importance of managing digital information in disaster response is well understood even outside IS. The volume of digital crisis-related information has been increasing due to at least three technological trends: (1) the miniaturization of communication technology; (2) improvements in remote physical sensing; (3) the pervasiveness of social media.

The pervasiveness and miniaturization of communication technology are evident from the popularization of mobile devices (Yoo, 2010, p. 215). In modern disasters, mobile devices enable humans to serve – perhaps unwittingly – as a distributed network of sensors, thereby increasing remote sensing capabilities. Truly, human sensing has been critical at least since 1968, when 9-1-1 first became available. However, the novelty is that mobile device allows for "opportunistic sensing" (Lane et al., 2010), which means that users may generate digital data streams of crisis-related information without even participating actively.

The second trend consists in the improvement of remote physical sensing capabilities, particularly through IoT, unmanned areal vehicles (UAVs), or satellite imagery. As for human sensing, physical sensing has been available for decades. For instance, while satellite imagery has been available since the early '70es (e.g., USGS EROS Archive records are available starting from 1972), images became publicly accessible only starting early '00.[1] That enabled even private

[1]For instance, the USGS Global Visualization Viewer (GloVis) is available since 2001 https:

organizations and research teams to experiment with satellite imagery. In Africa, for example, organizations in public health used satellite imagery to identify risky areas for Ebola outbreak, by looking at the concentration of palm trees where fruit bats (the harbor of the virus) congregate (National Center for Emerging and Zoonotic Infectious Diseases, (NCEZID), 2018).

Third, the popularization of social media showed how crises reflect onto – or even originate from (Oh, Eom, & Rao, 2015) – the digital space. While social media are not designed to support emergency management, the analysis of crisis-related information from social media magnetized scholarly attention (Bonaretti & Piccoli, 2018b), some reasons being the ubiquity, communication rapidity, and cross-platform accessibility of social media (e.g., Twitter and Facebook) (Yin, Lampert, Cameron, Robinson, & Power, 2012). In March 2012, the American Red Cross, in collaboration with Dell Technologies Inc., inaugurated the first Digital Operation Center (DigiDoc), with the goal to monitor activities in the digital social space during the aftermath of disasters. A similar center is also active in Australia (Yin et al., 2012, p. 54).

These novel IT-enabled opportunities to inform disaster response call for information system (IS) to become a reference discipline in guiding technology-enabled emergency management research. Instead, EMIS scholars lament a "limited understanding of the holistic socio-technical phenomenon of technology-supported crisis response" (Thapa, Budhathoki, & Munkvold, 2017, p. 19). This literature review provides an *understanding* (Rowe, 2014, p. 244) the current theoretical discourse in EMIS to assess the extent to which EMIS scholarship contributes to the core of the IS discipline. Specifically, we answer two questions:

1. Does EMIS research contributes to a theory of the core of IS?
2. Assuming EMIS scholars intend to contribute to an imported line of research, how to get a reference discipline to acknowledge the value of an IS perspective in advancing a reference discipline theory?

To answer those questions, we adopt a *problem-centered* focus on IT *use* for emergency management, and distinguish among different theoretical perspectives by grouping them following

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Gregor's (2006) types of theories. The benefit of using Gregor's taxonomy is to be suitable to categorize theoretical contributions from any discipline, and yet it is designed specifically to evaluate theoretical contributions within IS scholarship. To clarify the scope of this research, we highlight that:

1. The goal of this review is understanding of the current theoretical landscape
2. Our target audience is IS scholars interested in characterizing IS research in emergency management from other disciplinary perspectives
3. Our goal is not to criticize prior research as non-IS, but rather to show how it may contribute to a unifying body of knowledge in EMIS
4. While our review may inspire future research to explore the power of grand theories in EMIS, such goal exceeds the scope of this research

Thus, the goal of the review is to: (1) *synthesize* past knowledge in EMIS; (2) *identify biases* and knowledge gaps in the literature; (3) propose corresponding future *research directions* (Rowe, 2014, p. 243). Our contention is that the EMIS scholarship downplays seeking *native* IS theories for explaining and predicting – what (Gregor, 2006) calls a "type-IV" theories, which may serve as unifying *grand theories* for guiding the research program. One challenge for EMIS researchers will be to elect unifying *grand theories* to guide the EMIS stream of research (Gregor, 2006, p. 626). An eligible grand theory should be a native IS theory for both explaining and predicting, but, as this literature review shows, the theoretical fragmentation in EMIS hinders this exercise of theoretical synthesis.

2.2 Defining Emergency Information Systems (EMIS)

2.2.1 Emergency Management

Emergency management (EM) is the "managerial function which arranges countermeasures and coordinates involved organizations, resources and information to prevent, mitigate, respond to, recover from or prepare for a disaster and therefore reduce the overall vulnerability of communities and infrastructures to known and unknown threats" (Vogt, Hertweck, & Hales, 2011, p. 2). The term *emergency* may refer to events that span from routine criminal activities to natural and human-

made disasters, but we use it specifically to refer to large-scale crises which require prompt intervention. In our conceptualization, emergencies unfold in *chaotic contexts*, the "domain of rapid response" (Snowden & Boone, 2007, p. 5), under turbulence, unclear cause-effect relationships, and acute time pressure. Scholars distinguish among four phases of an emergency management (*see* Table 2.1): mitigation, preparedness, response, and recovery (Turoff et al., 2009). Most of the literature in EMIS, however, focuses on the response and short-term recovery phases, which constitute the core of "emergency management."

Table 2.1: The phases of the emergency management process

Phase	Definition
Mitigation	Includes long-term activities to prevent damages (e.g., defining areas at risk).
Preparedness	Actions aiming at improving resiliency (e.g., evacuation plans, stocking food).
Response	Emergency assistance right after the disaster outbreaks (e.g., rescuing victims).
Recovery	Short and long-term activities that are not characterized as emergencies, and do not occur under severe time pressure. Instead, they aim at restoring pre-crisis situations within the affected community (e.g., temporary housing, financial assistance).

2.2.2 Emergency Management Information Systems

The field of emergency management information system (EMIS) concerns with designing and evaluating information systems to support the EM functions. Scholars have stressed the practical orientation of research in EMIS, which should focus on the "functionality requirements that the software needs for those planning and executing the emergency response management function" (Turoff, Chumer, de Walle, & Yao, 2004, p. 3). That definition entails a broad range of archetypal information systems. A review of EMIS archetypal systems identified at least five (Adrot & Jessie, 2009): (1) geographic information systems for location and tracking; (2) risk assessment systems for risk identification; (3) internet response grids and collaborative virtual work-spaces for coordination; (4) decision support systems and intelligent agent systems to support decision making; (5)

databases and knowledge management systems to serve as repositories of knowledge. However, it seems difficult to define EMIS as an area that investigates the use of a specific set of archetypal systems which – one may argue – are not even peculiar to EMIS.

Another approach is to define EMIS by its theoretical concerns and relevant concepts. For instance, Turoff, Chumer, de Walle, and Yao, 2004 highlighted three design principles that are critical to study in EMIS: interoperability, timeliness, and uncertainty. While IS scholars so far have studied those concepts in contexts that lies outside EMIS, prior research shows what it means to study them from an IS perspective. For each of those three concepts, we discovered at least one study published in a top IS journal, which provides a starting point for studying those environmental stressors. For interoperability, Markus, Majchrzak, and Gasser, 2002 studied it within the design of systems for emergent knowledge processes (EKP). Systems for EKP are multi-actors operated systems whose roles and prior knowledge are unknown – hence *emergent*. Second, for the system use under time-pressure, Walls, Widmeyer, and El Sawy, 1992 discussed the design principles for vigilant, executive IS (EIS). EIS support decision making in turbulent environments by enhancing "the formulation of emerging issues" (p. 51). For uncertainty, decision-making under uncertainty is a vibrant research stream in IS that has been developing independently from emergency management. For instance, Ballou and Pazer, 1995 studied the accuracy-timeliness trade-offs to maximize a utility curve.

That shows how EMIS research, in spite of a narrow focus on system's use during emergency, may easily connect to the other scholarly discourses in IS. Scholars argue that one merit of EMIS research is to contribute to understand the environmental stressors that are typical of a crisis context, which is relevant to the IS field overall (Weick, 2010). That is because emergencies serve as fast-evolving scenarios and platforms for rapid testing. By taking a crisis as the observational unit, the researchers can narrow the time-space and mitigate the impact of the confounders at play. Thus, crises facilitate controlling for variability because of their self-contained nature: "if you watch a compact, specific, short event then you can grasp most of it with relatively few factors" (Weick, 2010, p. 537). That means EMIS scholarship enables scholars to formulate concepts that scale

to phenomena that are not necessarily disaster-related but share common environmental stressors with emergency scenarios. One example of such cross-pollination between IS and EMIS is social-media analysis. Disasters are ideal environments to study rumor-propagation on social-media. That is because disasters exacerbate the human tendency to seek information to comprehend the environment they experience (Winerman, 2009). In other cases, it is IS research that provides concepts that apply to the EMIS domain. For instance, a firm's reputation crisis on social media requires a timely response, and ways of rumor controlling, that are scalable to managing rumor on social media during a natural disaster.

2.3 Review of EMIS literature

Our literature review seeks to *understand* and *synthesize* (Rowe, 2014, p. 244) research in EMIS. The review is *problem-centered* on EMIS and shows the different types of scholarly contributions in EMIS. Adopting Gregor's (2006) theory types, we surface the merits and limitations of EMIS contributions, mapping the manuscript to each of the five theory types. Grouping by theory types helps cope with the theoretical heterogeneity that characterizes EMIS scholarship. More so than because of the archetypal systems being studied, heterogeneity arises from the high interdisciplinary and use of nonnative IS theories – for instance from mass communication, or sociology (Bonaretti & Piccoli, 2018b). Our research supports this finding by analyzing 35 unique theories distributed over 69 total articles between 2008 and 2018. The screening and coding processes of the manuscripts are described in A.1 (p. 95). Gregor's types offered a framework to synthesize this corpus of heterogeneous research, whose results we summarize in the following sections.

2.3.1 Type-I: Theories for Analyzing

Type-I theories are analytic theories including taxonomies, classification schema, but also "research on the delineation of constructs and their associated measure" (Gregor, 2006, p. 623). These theoretical contributions are not merely descriptive, but summarize the salient attributes of phenomena in the EMIS context. That is the case of literature reviews which, therefore, are included in this section.

The first group of studies we present addresses the "drop your tools" allegory (Weick, 1996),

which refers to the limitations of using routine approaches to respond to emergencies, which, instead, are non-routine phenomena by definition. Elaborating on the limitations of scholarship built on routine situations, one study reviewed the context-specific dimensions of use in chaotic environments (Adrot & Jessie, 2009). The authors identified ten key dimensions of use that are peculiar of IT usage in crisis situations; five dimensions concern the user (i.e., hyper-vigilance; computer self-efficacy; emotional pressure; nature of emotions; time pressure), three the task (i.e., information feedback; improvisation; coordination), and two the system (i.e., technological fit; flexibility).

To cope with non-routine situations, other studies elaborated on the notion of *improvisation*. One study warned against the tendency to understand improvisation as "abandoning standard procedures" (Adrot & Robey, 2008, p. 2). Revising prior definitions, the authors characterized organizational improvisation as "a collective process that involves a spontaneous deviation from established uses of resources and that requires coordination among actors who command resources" (p. 3). A second study, instead, insisted on the idea of improvisation and, in particular, on designing *frugal IS* that are resilient to catastrophes (Sakurai & Kokuryo, 2014). By looking at IT failures in the aftermath of the 2011 Great East Japan Earthquake, they review the design requirements for frugal, resilient IS, arguing against the "uselessness of planned solutions" (p. 5), and recommending to focus on the notion of "autonomous creative response" (p. 17) to increase the resilience of IS. Resilient information infrastructures should follow four design principles: (1) redundancy; (2) resourcefulness ; (3) robustness; (4) rapidity Also, (Hans Jochen Scholl & Patin, 2014).

Connected to studies in resilient IS, is the problem of disaster-generated communication barriers. A literature review of the communication barriers in crisis management, identifies three categories thereof: technological, organizational, and social (Fischer, Posegga, & Fischbach, 2016). The authors argue that communication barriers remain under-researched in two main areas: (1) intra-organization communication, because research mostly focused on inter-organization communication; (2) their generalizability to explain the behavior of the public, for instance with respect to their willingness to interact through social media. Another challenge for inter-organization com-

munication, is the coordination of the multiple intervening actors in the EMIS context. In that respect, one study categorizes the main impediments of relief-humanitarian logistic, which often relies on a network of smaller NGOs (Taylor & Arthanari, 2017). A major issue in humanitarian logistics pertains to the lack of coordination due to the low information visibility within the relief supply chain. The study concludes that the decentralization of the communication network helps develop self-healing capabilities of each node to cope with the disruption of emergencies.

Social media analysis is another area of interest which attracted type-I contributions. In an early review of social media sites as a repository for crisis-related information, the authors categorized the design requirements to transform social media in repositories of crisis-related data (Plotnick, White, & Plummer, 2009). They suggested social media constitutes an intuitive system for managing the vast amount of information, although the unstructured nature of the content hinders effective knowledge management. A second study classified data sources of crisis-related data, focusing on opportunities for real-time data analysis from social-media, mobile app, SMS/MMS communication (Michael A. Erskine, Christopher, & Hossein, 2013). Other studies have, instead, downplayed the potential of social media analysis for extracting relevant information. Scholars surfaced the critical concerns that emergency management agencies have when using information from social media (Gill, Alam, & Eustace, 2015, 2014). The authors assessed the ability to exploit social media and the relevance of social media analysis by isolating 24 social media-related issues distributed among four viewpoints: (1) the value of the information; (2) the financial and human resources required; (3) IT infrastructure and operability; (4) the social media management (e.g., policy and authority). A later study confirmed that information overload and limited resources to verify information from social media were still relevant barriers to institutionalize their use in crisis management (Shan, Plotnick, Hiltz, & Yang, 2017). Lastly, a review of studies in Volunteered Geographic Information during a crisis (VGI) lamented that scholars have mostly focused on how to extract VGI from social media, yet overlooking dedicated VGI platforms such as Ushaidi, or OpenStreeMap (Horita, Degrossi, Assis, Zipf, & Albuquerque, 2013).

2.3.2 Type-II: Theory for Explaining

Type-II theories for explaining the focus on understanding *how* and *why* a phenomenon occurs, yet softening the importance to formulate testable predictions. Typically, type-II develops from case studies and interpretative field studies; that is often the only option for EMIS scholars to study rare, hard to replicate, large scale events. Examples of type-II studies are those building on structuration theory (Kaewkitipong, Chen, & Ractham, 2012), an those drawing on Affordance and Activity Theory (Gibson, 1975) and Rumor Theory (Allport & Postman, 1947).

Studies drawing on *Activity* and *Affordance Theory* are popular in EMIS (8 articles, see the coding matrix in Table A.1, p. 99), particularly among journal publications. Affordance Theory (Gibson, 1975) is an ecological psychology theory that has found extensive application in IS scholarship in the last decade (Markus & Silver, 2008; Volkoff & Strong, 2013, 2006). Admittedly, Affordance Theory focuses on "how and why outcomes occur, rather than what outcomes occur" (Strong et al., 2014, p. 77) which is why we consider Affordance Theory as mostly type-II. Studying affordance means to focus on "potential for behaviors associated with achieving an immediate concrete outcome and arising from the relationship between an artifact and a goal-oriented actor or actors" (Strong et al., 2014, p. 69).

We highlight two main high-level merits of Affordance Theory before analyzing its impact on EMIS. The first, which perhaps explains its success in EMIS, is that Affordance Theory has developed as a framework to describe *collective* affordances, which exist only for groups but not for individuals. The notion of collective affordance easily scales to capture the collective dimensions of emergency management, hence the popularity of Affordance Theory as one of the few native IS approaches to study organizational phenomena in EMIS. Immediate affordances are *generative mechanisms* which may activate more complex and higher level affordances (Volkoff & Strong, 2013). For instance, "coordinating the relief operation" is a collective affordance that relies on more immediate affordances such as "inputting data," "viewing information," and other "immediate outcomes" (Strong et al., 2014, p. 69).

Affordance Theory has been adopted to study the actualization of connective affordances in

the aftermath of a disaster (Leong, Pan, Ractham, & Kaewkitipong, 2015; Tim, Pan, Ractham, & Kaewkitipong, 2017; Vaast, Safadi, Lapointe, & Negoita, 2017). That guided the understanding of how social media afford the actualization of community empowerment and enable the affected communities to reorganize themselves and to cope with the disaster (Leong et al., 2015).

The second aspect to clarify is that affordances are relationships that exist regardless of their actualization (Markus & Silver, 2008, p. 620) since they are *potential* for behaviors. Affordance Theory theory does not focus on deterministic predictions, hence its classification as a type-II. Scholars criticized the non-deterministic epistemology of Affordance Theory for downplaying the pursue of predictive knowledge, questioning whether Affordance Theory might have any analytic merit at all (Oliver, 2005, p. 412). In EMIS, Activity Theory approaches tried to overcome the limits of Affordance Theory by looking at goal-oriented and artifact-mediated *activity systems*, for instance for coordination (Allen, Karanasios, & Norman, 2014, p. 428), or information dispatching activities (Valecha, Rao, Upadhyaya, & Sharman, 2019). An *activity* is "a series of processing actions performed by a responder while providing response to chaotic event(s)" (Valecha et al., 2019, p. 41). A major difference with Affordance Theory is the attempt to expand the current system's capability through *changing actions* (Valecha et al., 2019, p. 37).

Another type-II research tactic is to combine Affordance Theory with theories from other reference disciplines; for instance, with sociology and mass-communication literature on Rumor Theory (Allport & Postman, 1947), which reflected research on social media analysis and *rumor-control*, or Audience Gatekeeping on social media (K. H. Kwon, Oh, Agrawal, & Rao, 2012; K. Kwon, Oh, Agrawal, & Rao, 2011). This line of research explores issues of rumormongering during crises – usually from social media – and how to reduce it. Rumor Theory posits that social crises engender the ideal conditions for the rumor to spread (Allport & Postman, 1947). During disasters, individuals experience emotional discomfort due to the shortage of reliable information and, to regain emotional relief, they become more vulnerable to unverified information (Liu, Burton-Jones, & Xu, 2014). Rumor-mongering fills such an information gap. However, because information typically flows through back-channels (e.g., social media, neighbors, etc.) there is no control on informa-

tion faithfulness and completeness, since rumor spreads according to emotional drivers such as importance (topic relevance) and ambiguity (of the environment) (Oh, Agrawal, & Rao, 2013).

2.3.3 Type-III theory: Theory for Predicting

Type-III theory aims at explaining the *what* rather than the *why* of an event (Gregor, 2006, p. 625). Examples are predictive theories that build on algorithmic approaches and statistical techniques, which provide limited theoretical explanatory power and understanding of the causal underpinnings. Type-III contributions hardly reach top IS outlets, both in EMIS and in IS in general – Gregor classified only 2 percent of the publications she analyzed as type-III. They draw on statistical regularities, which may highlight technological pattern regularities in systems' use to inspire more theoretically grounded research. For instance, a study focused on the application of satellite imagery for disaster assessment during forest fires (Lestari, Rumantir, & Tapper, 2016). The study shows that satellite imagery can identify active fires, and predict risky areas based on land cover types and locations of a previous fire. However, there are other factors that satellite imagery does not capture, such as the presence of human activity. For that reason, remote-sensed information has to be complemented with on-ground information.

What dominates type-III contributions is the analysis of social interaction on the social space, Twitter in particular. For instance, one study used a Naive Bayes classifier to predict social presence on Twitter (Mukkamala & Beck, 2017). The authors argued that higher levels of social presence in the aftermath of a disaster are beneficial for human bonding. For that reason, it is critical to monitor social interaction in the digital space. Another study analyzed conversations on Twitter in the aftermath of the 2016 Brussels Bombing to understand what types of information diffuses on social media (Mirbabaie & Zapatka, 2017). The tweets show the disseminative role of "amplifiers", who broadcast information from "information starters" to "transmitters." Practitioners should focus on managing the amplifiers' retweeting patterns because the latter has the capability of reaching a larger network of users than the information starter themselves. Thus, amplifiers have the highest impact on collective sense-making. A similar attempt to identify dominant accounts presents an approach to *ego analysis*, which means to measure users' centrality in the aftermath

of a flooding event (F. Cheong & Cheong, 2013, 2011). The authors unsuccessfully attempted to identify central users on Twitter and then use their connections to extract crisis-related information.

Another relevant field is supply chain and resource allocation during crisis response. One study focused on a method to identify activities during the emergency response that are not operable due to conflicts of research allocation (Sackmann, Hofmann, & Betke, 2013). For instance, because of place-related inconsistencies, or because the required resources are not available. While the intended use of their model is to support the decision-making of emergency managers, their research focused on developing an algorithmic approach to allocate resources.

2.3.4 Type-IV theory: Theory for Explaining and Predicting

Type-IV theories seek the underlying causes of *why* something happens. They pursue both predictive and explanatory intents. According to Gregor, 2006, p. 626–628, examples of type-IV theories are Information Systems Theory, Information Success Theory, Technology Acceptance Model, as well as the first formulation of Representation Theory (Weber et al., 1997). Type-IV includes "grand theories" to guide a whole research program. One benefit of a *native* IS grand theory is to constrain the research program to a dependency path towards disciplinarity. However, we did not find articles that adopted a native type-IV theory. Scholars, instead, mostly applied nonnative grand theories to study how technology reshapes traditional EM practices.

One study proposes a theory for studying the information and communication processes of volunteer communities (Sebastian & Bui, 2009). The authors call for including behavioral and organizational aspects in the system's design. Helping members of the community in need relies on the individual sense of obligations towards the victims; thus system design should consider motivational aspects for engaging volunteers to support, for instance, inter-organizational collaboration (Yates & Paquette, 2011) and coordination (Adrot & Robey, 2008) during emergencies.

In that respect, some scholars noted that social media became a facilitator for connectivity among like-minded actors, who are more capable to self-organize and respond to crises (Majchrzak & Malhotra, 2013). That called for studying the elements of the design of the social media platform to improve inter-organizational collaboration (Valecha, Sharman, Rao, & Upadhyaya, 2012), and

how to leverage social media for constructing a shared understanding among social groups (Oh et al., 2015). Here, the focus is on how technology (e.g., social media) may facilitate the emergence of new social structures, such as the bottom-up ephemeral organizational structures of volunteer groups.

2.3.5 Type-V theory: Theory for Design and Action

Type-V theories say *how to do* something (Gregor, 2006, p. 628), and include theoretical perspectives with prescriptive relevance. They are often exploratory, and prioritize applicable knowledge over formal theory development. For instance, type-V knowledge may help scrutinize unexplored technological affordances (e.g., how to use satellite imagery to support emergency response?). Its merit is informing the investigations of new IT solutions, although the potential for a theoretical contribution sometimes remains unrealized. Action Research and Design Science contributions are the core of type-V contributions (Gregor, 2006). Since design science contribution may draw on type-II or type-IV theoretical bases as well, being type-V does not rule out an ancillary contribution of different types. For instance, one study built on the Technology Acceptance Model (Davis, 1989) to develop an Action Design Research (ADR) approach for evaluating EMIS decision support systems (Neville, O'Riordan, Pope, & 'Lionird, 2018). The authors highlight that ADR in EMIS is particularly challenging because it is difficult to involve appropriate stakeholders and evaluate the system in realistic scenarios. Their ADR approach calls for an "all-phases approach to EM" (p. 14), which means to design modular decision support systems that integrate well with other existing systems to support a broad range of emergency scenarios.

Following this interest for integrated EMIS, a design science study on integrated information platforms studied the design of a system for increasing situational awareness of fire commanders (Yang, Su, & Yuan, 2012). The authors argued that those users are unlikely to accept systems that provide too much automation and exclude commanders from the decision-making loop. Thus, they stressed that the role of the EMIS is to support decision making thanks to three enabling factors (p. 765): (1) to facilitate clear communication; (2) to improve the efficiency and effectiveness of decision making; (3) to manage the data to prevent information overload. Following a similar

holistic approach to emergency response, another study proposed a step-by-step guide for setting up an IT-supported information flow network (Pan, Pan, & Leidner, 2012). The authors discovered four different forms of information networks, which differ by information- and network-intensity levels. Their research stresses the importance for emergency managers to assess the organizational factors that help scrutinize the information network structure that may work best. Then, they provide specific information flow strategies to proceed with. For instance, when there is no central organization, or existing relationships between relief organizations are poor, such as during response to 2005 Hurricane Katrina, high information flow is hard to achieve. In those cases, the attempt to set up a strong command structure hampers the flexibility of the individual agencies, without benefits for the network of the responding agencies overall. Under those circumstances – the authors argue – "Because there is no trusted, central crisis response organizer...the different IT infrastructure of the different responding agencies from a boundary...[Thus] IT is more of an inhibitor of effective crisis response than an enabler" (p. 46).

2.4 Discussion

Our attempt to characterize the articles by how their contributions map to a theory type enables scholars to reflect on "the nature of the statements that can and should be made within that theory type" (Gregor, 2006, p. 633). Eventually, that was the intended goal of Gregor's taxonomy, which in this section we contextualize to EMIS. In the following paragraphs, we revisit our research questions to address: (1) How EMIS contributes to a theory of the core of IS; (2) Why a holistic approach may serve to knowledge accumulation; (3) the importance to draw on native theories while maintaining an interdisciplinary perspective.

2.4.1 Does EMIS research contribute to a theory of the core of IS?

Our review shows that emergency management is cross-disciplinary and characterized by theoretical fragmentation. Other disciplines dealing with emergency management suffer similar methodological and theoretical fragmentation; for instance, organizational scholars lamented excessive practitioner-focus (i.e., by building on descriptive case-studies) which hampers the theoretical understanding of emergencies (Buchanan & Denyer, 2013, p. 210). However, EMIS outstrips theoret-

ical fragmentation with a lack of disciplinarity, often drawing on nonnative IS theories (Bonaretti & Piccoli, 2018b). The problem of disciplinarity is mitigated among journal articles, where we showed that EMIS research largely contributed to the Affordance and Activity Theory discourses, which are core in IS research. That shows EMIS research has indeed contributed to the core of IS by contextualizing type-II theories to system use during emergencies. However, there has been a lack of interest in contributing to type-IV theories. Seeking native type-IV theories that may serve as grand theories could support unifying perspectives in EMIS scholarship, facilitating both knowledge accumulation and the pursuit of disciplinarity.

Seeking a holistic approach to facilitate knowledge accumulation

Unnecessary fragmentation of the theoretical approaches hinders the accumulation of scholarly knowledge (Hirschheim, Klein, & Lyytinen, 1996). Thus, it is unsurprising that EMIS authors lament a limited understanding of technology-supported emergency management as a holistic sociotechnical phenomenon (Thapa et al., 2017, p. 19). Prior attempts to propose holistic framework for EMIS pointed to the Resource-based view (Chen, Rao, Sharman, Upadhyaya, & Kim, 2010) and Actor-network Theory (Thapa et al., 2017). However, those approaches pursue unification but not *disciplinarity*. The problem when drawing on nonnative or "imported" (Straub, 2012, p. v) theories, is that "the less IS researchers recycle paradigms from reference disciplines...the more likely they will build cumulative tradition" (Hassan & Mingers, 2018, p. 575), since non-disciplinarity exacerbates fragmentation.

Theoretical fragmentation hinders the cross-referencing of research findings and knowledge accumulation while encouraging "piecemeal research tactics" (Hirschheim et al., 1996, p. 3). Instead, a holistic framework provides criteria to evaluate what falls within the boundaries of IS research (Weber, 2003, p. ix), ensuring focus and measure correspondence (Rai, 2016, p. vii). Theoretical unification facilitates the accrual of scientific knowledge and decreases *inclusion error*, which is the "examination of constructs best left to scholars in other disciplines" (Benbasat & Zmud, 2003, p. 190). Although cross-disciplinary research naturally leans towards theoretical heterogeneity, a common conceptual framework helps cross-relate the results based on shared theoretical and

epistemological origins (Hirschheim et al., 1996, p. 4). Its role is to guide the interpretation and understanding of different research problems and to facilitate cross-pollination between uncoordinated research efforts (Hirschheim et al., 1996, p. 5). To fulfill those goals, future scholarship may develop theory that encourages unity on disciplinarity in EMIS.

Pursuing disciplinarity by drawing on native theories

Scholars are advocating for research strategies in IS that are "disciplinary while being interdisciplinary" (Rai, 2017, p. vi). To do so, IS research should pursue disciplinarity and build on native IS theories (Rai, 2017). Scholars suggested that pursuing disciplinarity means to orient IS research towards its core: studying the *effective use* (i.e., usefulness) of a system (Burton-Jones & Grange, 2013). Seeking a native IS approach is synergic with the goal of moving IS toward a more prominent role as a reference discipline for other fields (R. L. Baskerville & Myers, 2002). The risk, instead, when adopting nonnative theories, is to tailor the EMIS research agenda to nonnative research agendas. While EMIS scholarship awaits a conceptualization of what it means to address EM problems from an IS perspective, the call for disciplinarity, intertwined with one for knowledge accumulation, promotes an ideal scenario: pursuing knowledge accumulation to extend native IS theories.

2.4.2 How to get other disciplines to acknowledge the value of an EMIS perspective in advancing a IS nonnative theory?

While we highlighted some concerns about inter-disciplinarity of EMIS, we are not suggesting that only contributions that build on IS core theories should account as EMIS. At the same time, we note that prior research cautioned against extensively adopting non-native theories in IS research. In particular, scholars warned against the risk of focusing on *information technology*-related phenomena, rather than *information systems*-related phenomena, arguing that IS scholars should focus on the latter (Weber, 2003, p. vi). Information technology-related phenomena, instead, are more apt to develop into a theory of the artifact, or minor revisions of existing theories (Weber, 2003). However, when the organic characteristics of IT artifacts falsify non-native theories or lead to major revision thereof, an opportunity arises for IS research to become a reference discipline. To explore

whether information technology-related phenomena may as well contribute to the core of EMIS, scholars need to enable IS perspectives to communicate with non-native ones. We propose that one way to facilitate this process is by converging and drawing on commonly understood ontologies that enable cross-theoretical and cross-disciplinary communication. This cross-pollination happens at the most superficial level (type-I) since researchers do not need to share an overall theoretical perspective. Shared ontologies help link pieces of research by creating a common ground for comparison. While not professing completeness, we identified three enablers of such cross-pollination. First, the understanding of the notions of frugality and *improvisation* in system's development as strategies to cope with the crises. Second, the focus on social interaction on the digital social space during crises, particularly on Twitter. Third, the focus on *situational awareness* as the intended outcome of using a system for disaster response. The next three sections elaborate on how these three elements enable cross-pollinating.

Improvisation in EMIS

Emergencies, especially catastrophic ones, pose challenges that maybe unprecedented and difficult to tackle with routine solutions. Emergency management science has extensively discussed the notion of "dropping your tools" (Weick, 1996), an allegory that depicts emergency management as mainly entailing exception-handling, where routine procedures are unlikely to work and improvisation is critical. Some IS scholars have embraced the notion of "frugal IS" (Watson, Kunene, & Islam, 2013) to indicate systems that are developed under time and resource constraints to cope with the failures of routine (or disrupted) systems in the aftermath of a disaster. Nonetheless, a large part of the articles we reviewed disagrees with the "useless[ness] of planned solutions" (Sakurai & Kokuryo, 2014, p. 5). Allen et al., 2014, p. 420 argue that first responders are unlikely to use systems effectively if they have been patched together when a disaster outbreaks. The idea to deploy dual-use systems that are used outside major incidents calls to reduce improvisation and assumes that individuals use systems effectively only if system use becomes routine (Allen et al., 2014, p. 428). Connecting improvisation in system's use with the broader narrative on process improvisation is one way for IS to expand to show how IT may enhance or constrain improvisational

capabilities.

Social media and their effective use

EMIS scholarship has intensively focused on social-media analysis (24 manuscripts, 40 percent of the 69 total articles in our review). Fifteen years into the era of social media, scholars have achieved a good understanding of social media affordances. Nonetheless, the practical relevance of social media analysis for supporting emergency management is still unclear. Research that investigates the effective use of social media for disaster response is still lacking or inconclusive. Scholars, even outside our community, cautioned against "the tiranny of the tweet" and to shift the investigation to understand "design in use" of IT (Palen & Anderson, 2016, p. 224-255). Based on our review, one reason for the interest in social media analysis is the possibility for researchers to contribute to studying rumor propagation. Rumor propagates easier in a world where the social ties are digital, therefore characterizing digital rumor during disasters in unique ways compared to non-digital rumormongering (Li, Sakamoto, Chen, & Tanaka, 2014; Liu et al., 2014; Oh et al., 2013). Moreover, SM such as Twitter enables tracking back the genesis of each thread, thus facilitating the analysis of digital rumor. Following Weber, 2003, this is a scenario where EMIS research, while not contributing to the core of IS, has a chance to become a reference discipline by explaining the unique impact of IT on a known phenomenon (i.e., rumor propagation).

Tracking rumor during crises is important for two reasons. The first, which is implicitly embraced by many type-III contributions, is that rumor deteriorates information quality. That hinders the extraction of accurate information from SM both for victims and responders. But again, it is unclear to what extent even rumor-free information from social media is useful to emergency responders. What do we expect to attain with rumor free information from social media? What is the intended use of a system that leverages social media information? A response to those questions should then move to consider how information from social media compares to sources from emergent technologies for remote sensing (e.g., satellite imagery, UAVs, IoT) that are accessible with less effort. Meanwhile, public expectations on SM are increasing: 42 percent of American adults expect their municipality to "listen" to social media during emergencies (Carter, Thatcher,

& Wright, 2014, p. 1975). That calls for more type-III theories to investigate the ability to extract faithful crisis-related information from SM. However, this early line of research remains limited to IS conferences.

The second – and perhaps more interesting – reason, is that unverified information decreases the population's morale and increase anxiety (Oh, Kwon, & Rao, 2010). Sentiments such as anxiety infiltrate collective sense-making platforms such as SM that may spark sociotechnical crises of its own by triggering deleterious collective action. Thus, it is important to understand rumor on messages retransmission (Liu et al., 2014) and how to control and mitigate it (Oh et al., 2010). For instance, IS scholars consider Twitter an enabling factor of the Arab Spring (Oh et al., 2015), which is an example of social crisis.

Situational awareness as dependent variable

The concept of situational awareness (SA) as the desired outcome of system use is recurrent in our literature. Within the articles in our sample, 10 manuscripts adopt SA to some extent. SA links to a more general discourse on decision science. The most recent formalization of the construct that we are aware of is in Endsley's *Model of Situational Awareness* (Figure 2.4.2). She defines situational awareness as "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future" (Endsley, 1995, p. 36). Early EMIS literature adopted SA and applied it to real-time decision making processes, maintaining that SA is a three-steps process entailing the abilities to *monitoring and perceive*, *comprehend*, and *project* (Lerch & Harter, 2001, p. 66). In EMIS literature, however, SA appears sometimes disconnected from its seminal conceptualization by Endsley, 1995. A.3 summarizes the volatility in defining SA among the articles in our sample – whenever a definition was actually available. Other authors link more explicitly their research to scholarship in situational awareness (Yang et al., 2012; Neville et al., 2018). They propose that EMIS should pursue a SA-oriented design of decision support systems, thus showing how Endley's model may serve as a type-V theory. Others propose SA as the intended outcome of data modeling in EMIS contexts (Valecha et al., 2012), stressing its importance as the outcome variable.

We reconcile prior definitions and define SA as an ideal status of intelligibility of digital representations of an event, within a volume of time and space, which enables the assessment of the projected effectiveness of actions on the environment of interest. The SA model holds an "ostensive" definition (Latour, 1984, p. 272) of SA, which focus on "projecting" the impact of actions, rather than their actualization. While SA *enables* projecting the effects of actualizing an action, it is insufficient to guarantee the effectiveness of such action. Future research will need to clarify how a higher level of SA, enabled by the IS, may improve the performance of the overall emergency management work system.

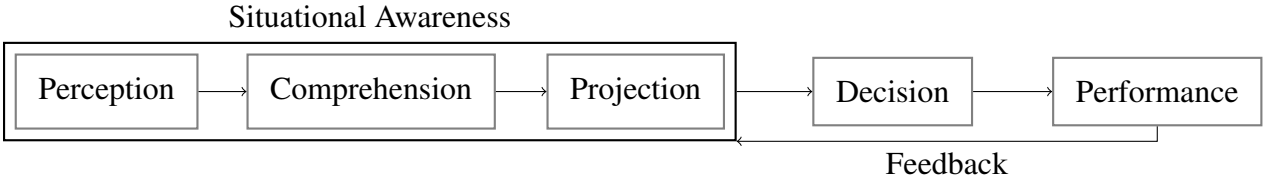

Figure 2.1: Endley's Model of Situational Awareness

2.4.3 Summary

Overall, Figure 2.2 depicts the theory development strategies that we foresee for the development of a core of EMIS research. Our analysis has highlighted two main "forces" that may bind scholarship to orbit around the EMIS core. A centripetal force, which is that of scholarship drawing on native IS theories. That force pulls emergency management phenomena – perhaps well understood in other disciplines – under the IS lens. A centrifugal force, which draws on shared ontologies with other disciplines. That force serves to connect EMIS scholarship to the emergency mamagement discourse in other disciplines. While the two forces apparently push in opposite directions, they are both critical to preserve the core of EMIS.

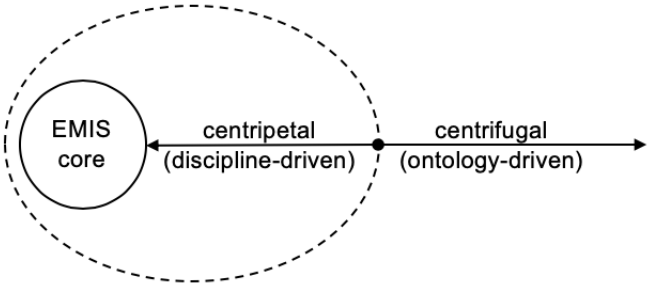

Figure 2.2: The *centripetal* and *centrifugal* forces of disciplinarity

2.5 Limitations

As we stated in the introduction, this review focuses on a narrow set of academic outlets. Of course, we are aware of relevant contributions in EMIS in other journals which we have not included. However, the merit of our research is to show what theoretical perspectives have had access to top IS journals, and where the debate may focus on during the next years based on conference proceedings. It is not an attempt to comprehensively review EM research in all its sprawling ramifications.

Among the articles that we included, some do not specifically investigate how to *manage* an emergency, but rather how a system may offer a digital representation of it (Vaast et al., 2017; Oh et al., 2013). Nonetheless, we included them in an attempt to be as comprehensive as possible in scrutinizing articles about the relevant context. At the same time, we excluded conference proceedings specific to emergency management (e.g., ISCRAM) which are unlikely to impact the theoretical discourse in IS overall.

Another limitation is whether the lack of type-IV theory that we point to should be a concern at all: perhaps EMIS researchers are simply not interested in generating testable propositions or converging towards a unifying perspective. For instance, scholars have argued that knowledge accumulation is possible through a one-step process of "understanding", consisting in developing *applicative knowledge* (Hirschheim, *forthcoming*) without drawing on a "grand theory." While that may be the case, we still point to the problem we raised about disciplinarity, which remains currently unaddressed.

2.6 Implications

The main implication of our work for EMIS scholarship is a call for seeking theoretical perspectives that pursue disciplinarity and knowledge accumulation. In this section, we discuss the implication of our call for the general context of EMIS research and social media analysis in EMIS.

2.6.1 Implication for EMIS scholarship

Our call for disciplinarity and unification assumes that organizing prior research under a holistic IS framework may help understand emergencies as socio-technical problems. A holistic approach helps scholarship to avoid compartmentalizing in disconnected research silos, which hinders rather than facilitates the emergence of new ideas (Hirschheim et al., 1996, p. 5). While some scholars encourage pursuing holistic and disciplinary approaches (Rai, 2016), others disagree that seeking holistic perspectives has any value whatsoever (Treiblmaier, 2018).

Moreover, developing a holistic approach calls for investigating: (1) whether scholars can meaningfully recast EMIS questions as mostly questions of IS use; (2) to understand what is peculiar of system use during emergencies. Currently, EMIS literature comprises diverse classes of issues and artifacts in supply chain, collaboration, communication, and coordination. But moving from an IS use perspective may still allow scholars to address a wide class of questions. For instance, a native IS perspective could recast technology-mediated organizational phenomena as problems about systems' interdependencies-in-use (Karsten, 2003). In that case, a holistic, native IS perspective may provide competitive socio-technical explanations to organizational phenomena that, so far, have been investigated in EMIS from nonnative theoretical perspectives. The ability for IS approaches to stand out against competitive nonnative ones, is a possible path to establish a IS core (Weber, 2003).

2.6.2 Implication for scholarship on social media for EMIS

In our literature review, 24 manuscripts (40 percent of the 69 total) studied to some extent social media use during crises (Figure 2.6.2). Twitter, as we pointed out in the introduction to this, has magnetized both scholarly and institutional attention. Anecdotal knowledge, echoing in scientific

literature (Acar & Muraki, 2011), depicts social media as a useful source of crisis-related information, which lead to assume that "extracting information from social media should make sense and be beneficial for crisis management" (Stieglitz, Mirbabaie, Fromm, & Melzer, 2018, p. 6). Despite the attention for social media analysis, scholarship has largely rested on type-III contributions. The risk, however, is to calibrate theory development on information technology-related phenomena rather than information systems-related ones (Weber, 2003). A definition of what it means to use social media effectively has yet to emerge, although prior research has surfaced a broad spectrum of social media affordances in EMIS. The development of type-IV theory will help define and assess how to actualize those affordances effectively, and to leverage crisis-related information from interactions in the digital social space.

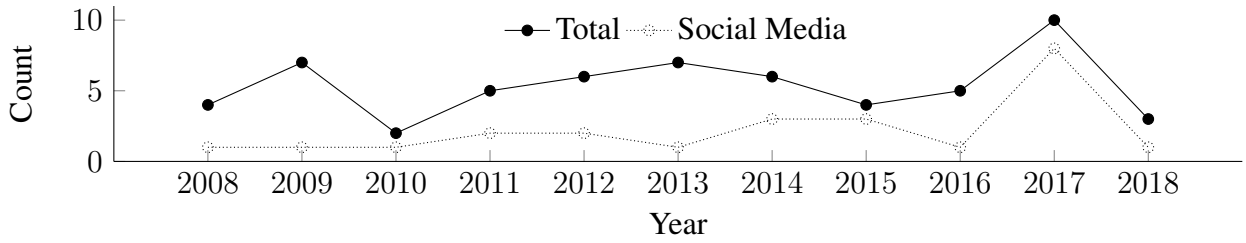

Figure 2.3: Distribution of manuscripts studying social media during 2008-2018

2.7 Conclusion

The increasing relevance of technology in supporting disaster response lead scholarly interest towards different theoretical and disciplinary trajectories. Among the articles we identified, however, heterogeneity ignored type-IV native IS theories, which should be the core of IS scholarship. Thus, researchers are left without a grand, native IS perspective for both *explaining* and *predicting* (Gregor, 2006) to guide the EMIS discourse. We argue that: (1) a holistic approach facilitates knowledge accumulation; (2) drawing on a native theory facilitates pursuing disciplinarity.

We show that the body of knowledge in EMIS is developed enough to enable pursuing both objectives. First, some scholars have framed EMIS research by using native, but not type-IV, theories (e.g., Affordance Theory). Second, there is a tendency to pursue a universal language that, while not explicitly formalized, has emerged from our review. A clearer formalization of this language would also facilitate cross-pollination with nonnative theoretical perspectives. For

instance, we noted how the construct *situational awareness* appears in several pieces of research, despite the different theoretical perspectives they adopt. Then, a relevant research question for future research may be: how can we use IT to increase situational awareness during emergency management? The challenge, however, remains to frame the response to that research questions drawing on native type-IV theories.

CHAPTER 3
EFFECTIVE USE OF INFORMATION SYSTEMS IN CHAOTIC ENVIRONMENTS

3.1 Introduction

IT-enabled systems to support emergency response and the digitalization of crisis-related information sources has stimualted scholarly interest in the socio-technical aspects of emergency management. In the 2013 World Disasters Report, the authors noted that "when disaster strikes, access to information is just as important as food and water." Disaster response is largely an information management problem. However, IS scholarship has not capitalized on the opportunity to lead the investigation of IT-enabled EM (Bonaretti & Piccoli, 2018b). One reason is that scholarship in emergency management information systems (EMIS) tend to draw on nonnative theories for understanding the impact of IT in emergency management (Bonaretti & Piccoli, 2018b). As a result, scholars lament a "limited understanding of the holistic socio-technical phenomenon of technology-supported crisis response" (Thapa et al., 2017, p. 19). The developing of a holistic understanding requires theoretical instruments to support EMIS research as a cohesive stream of research. Our research contributes pivots on the notion of system's effective use to develop a holistic theoretical perspective for EMIS. Developing a unifying *grand theory* to guide a research stream is critical to define its *nature* and *purpose* (Gregor, 2006, p. 626), and to guide researchers to the IS core in EMIS research. According to Effective Use Theory (EUT), the nature of all information systems is to be *representational artifacts* (Burton-Jones et al., 2017), and the purpose of the IS investigation is to study their *effective use* as such (Burton-Jones & Grange, 2013). However, the full extent of the promise of EUT it is still an open question, which this research discusses in the EMIS context. Admittedly, it is our working bias that a more insightful way to use technology effectively may develop out of a EUT perspective. That depicts our theorizing as conjectural, probing, and relying on the extent to which researchers will welcome our endeavor, that we summarize in the RQ: *How to use EUT to orient scholarship in EMIS?* To cope with the complexity and broadness of our research question, we break it down in two parts, each mapping to a section of this manuscript. The first presents the research problem and articulates the research

objectives of our theory development. That means to respond to three questions regarding EMIS: (1) What is the value of a holistic approach? (2) What is the value of disciplinarity? (3) What is the value of focusing on effective use?

The second part of the manuscript concentrates on theory development following three steps: (1) *understanding* where the discourse in EUT is currently at; (2) *problematizing*, to scrutinize what assumptions in EUT are problematic in chaotic context; (3) *conjecturing*, to discuss how the violation of assumptions may lead to adjust EUT. Here, we summarize the scope of each step, which serves as problem statements.

The section on *understanding* reviews the current status of the discourse in EUT concerning chaotic environments (e.g., emergencies). EUT moves from a Representation Theory (RT) perspective (Wand & Weber, 1995) to investigate how the system-in-use enables the faithful representation of a real-world domain (Burton-Jones & Grange, 2013). However, the validity of RT in chaotic environments is still uncertain (Burton-Jones et al., 2017); that raises a generalizability issue that propagates to EUT, and to the ability to apply EUT to chaotic environments, such as emergencies, as-is. The generalizability of RT is questionable because it "was conceived implicitly with a simple and perhaps a complicated context in mind – for instance, operational control and management control contexts." (Burton-Jones et al., 2017, p. 1324). During emergencies, instead, the presence of time-constraints and unclear cause-effect relationships calls for re-discussing the representational nature of the an IS (Burton-Jones et al., 2017, p. 1324). That is the objective of our second section: *problematizing*.

Problematizing focuses on how environmental stressors (e.g., time-constraints and unclear cause-effects relationships) impact the current understanding of EUT. This section derives the assumptions from EUT and articulates how emergency may violate them. The implications of violating assumptions are discussed in the third section, *conjecturing*.

Our *conjecturing* attempts to solve the disconfirmed assumptions that surfaced from problematization by using disciplined imagination (Weick, 1989). This approach to theorizing draws on plausibility as a surrogate of validity (Weick, 1989, p. 528), where plausibility is derivative of

prior empirical research in EMIS.

Our theorizing results in a set of testable propositions and principles to guide the EMIS research agenda. Assessing EUT in chaotic environments equips researchers with a theoretical instrument to reorient scholarship in EMIS to seek unification and disciplinarity (Rai, 2016) within the EMIS research agenda. Meanwhile, we also contribute to the concurrent discourse in EUT, and the call to assess RT in chaotic environments (Burton-Jones et al., 2017).

Finally, we offer a stylistic note to the benefit of the reader. The narrow focus of this research has often lead us to elaborate based on specific sections of a particular study, rather than from the results overall. Therefore, whenever possible, we point to specific pages in prior articles, with the intent to help the reader identifying the source of our claims.

3.2 Research Context

3.2.1 Emergency Management

An emergency management information system (EMIS) is one that supports emergency management, the "managerial function which arranges countermeasures and coordinates involved organizations, resources and information to prevent, mitigate, respond to, recover from or prepare for a disaster and therefore reduce the overall vulnerability of communities and infrastructures to known and unknown threats." (Vogt et al., 2011, p. 2). An EMIS is typically deployed in a *chaotic context*, the "domain of rapid response" (Snowden & Boone, 2007, p. 5), under turbulence, unclear cause-effect relationships, an acute time pressure. Scholars generally distinguish among four phases of emergency management which present different environmental stressors (Table 3.1): mitigation, preparedness, response, and recovery (Turoff et al., 2009). Response and short-term recovery are those which suffer chaotic environmental stressors the most, attracting the largest interest from EMIS' scholars.

Table 3.1: The four phases of emergency management

Phase	Definition
Mitigation	Includes long-term activities to prevent damages (e.g., defining areas at risk).
Preparedness	actions aiming at improving resiliency.
Response	Emergency assistance right after the disaster outbreaks (emergency management).
Recovery	Short and long-term activities that are not characterized as emergencies, and do not occur under severe time pressure. Instead, they aim at restoring pre-crisis situations within the affected community (e.g., temporary housing, financial assistance).

3.2.2 Emergency Management Information Systems (EMIS)

Adopting an IS perspective on emergency management (EMIS) means to study how technology supports, with real-time digital information, the understanding of the domain to cope with emergencies. It studies how to use information systems for creating digital representations of emergencies to support disaster response. To distinguish EMIS from other disciplines concerned with emergency management, some scholars suggested that the distinctive approach of the EMIS researcher is to depict emergency personnel as "knowledge workers" who rely on IT to support their intuitive understanding of the domain and "to reduce the risk for the public and mitigate the loss of life" (Klashner & Sabet, 2004, p. 62).

Scholars have studied how IT supports EMIS at an individual, organizational, inter-organizational and societal level, and spanning over a broad spectrum of archetypal technologies (see Figure 3.1). At an individual level use are, for example, scholars studied warning systems (Han, Ada, Sharman, & Rao, 2015). Their intended use is to provide users with digital representations of a threat to enabled them protecting themselves. At the group level are systems that support groups of people working together, for example: on-site information systems for coordinating first responders (Yang, Prasanna, & King, 2009); dispatching systems for resource allocation (McNab, Hess, & Valacich, 2011); systems for information sharing among different government agencies (e.g., local government, police, etc.) (Allen et al., 2014; Yang et al., 2012) and NGOs (Wakolbinger,

Fabian, & Kettinger, 2013). At an inter-organizational level are technologies to support coordination. At a societal level, social media enables the population to gain community intelligence (Oh et al., 2013), or where the population serves as sensors embedded within a broader information infrastructures; such as using smart-grids for extracting crisis-related information (Klashner & Sabet, 2004).

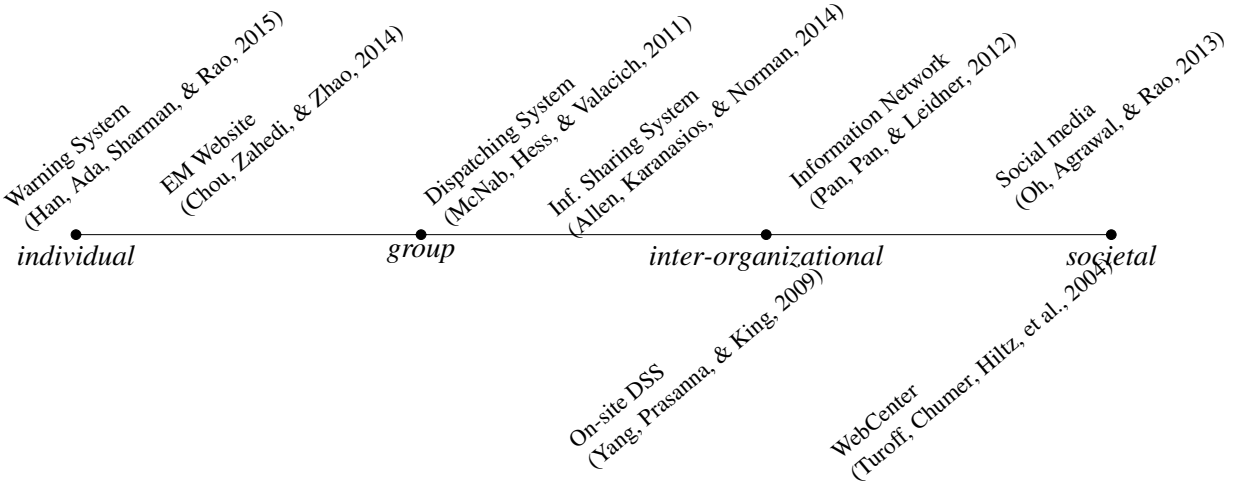

Figure 3.1: Archetypal systems for emergency management sorted by their level of analysis

3.3 Research objective: a unifying IS framework for EMIS scholarship

Because emergency management (EM) is in itself inter-disciplinarity, the challenge for EMIS researchers is to frame and position those interdisciplinary questions for an IS audience; hence, the need to pursue disciplinarity while being inter-disciplinary (Rai, 2017, p. vi). A native IS grand theory, that serves as a unifying framework, encourages disciplinarity by orienting the research agenda towards the unique IS aspects in the problem formulation. Low disciplinarity, instead, exacerbates the issue of theoretical fragmentation, since it disperses theoretical approaches not only within IS, but also among different disciplines (Bonaretti & Piccoli, 2018b). In this section, we explain why that is a concerning point, although perhaps not one that is peculiar to IS. Other disciplines too, such as organizational studies (Hllgren, Rouleau, & De Rond, 2018, p. 113), lament that studies in emergency management tend to be excessively practitioner-focused, and to build on descriptive case-studies that downplay the theoretical understanding of emergencies from an

organizational perspective (Buchanan & Denyer, 2013, p. 210).

Thus, we articulate the objectives of our inquiry as follows:

1. Seeking a holistic approach to facilitate knowledge accumulation
2. Pursuing disciplinarity by drawing on a native theory
3. Focusing on a Representation Theory perspective of effective use – i.e., Effective Use Theory

3.3.1 Seeking a holistic approach to facilitate knowledge accumulation

Some scholars argued that unnecessary fragmentation of the theoretical approaches hinders the accumulation of scholarly knowledge (Hirschheim et al., 1996), which hampers the understanding of technology-supported emergency management as a holistic socio-technical phenomenon (Thapa et al., 2017, p. 19).

Theoretical fragmentation hinders the cross-referencing of research findings and knowledge accumulation while encouraging "piecemeal research tactics" (Hirschheim et al., 1996, p. 3). Some advantages of a holistic framework are, instead, (1) to provide criteria for evaluating what falls within the boundaries of IS research (Weber, 2003, p. ix); (2) to ensure focus and measure correspondence (Rai, 2016, p. vii); (3) to help cross-relate the results based on shared theoretical and epistemological origins (Hirschheim et al., 1996, p. 4); (4) to guide the interpretation and understanding of different research problems and to facilitate cross-pollination between uncoordinated research efforts (Hirschheim et al., 1996, p. 5).

Overall, theoretical unification facilitates the accrual of scientific knowledge and decreases – when coupled with the pursuit of disciplinarity – *inclusion error*: the "examination of constructs best left to scholars in other disciplines" (Benbasat & Zmud, 2003, p. 190). A common conceptual

Prior attempts to propose holistic framework for EMIS pointed to the Resource-based view (Chen et al., 2010) and Actor-network Theory (Thapa et al., 2017). However, those approaches pursue unification but not *disciplinarity* – they are not native IS theories (Straub, 2012, p. ix). Drawing on nonnative IS theories clashes with the idea that "the less IS researchers recycle paradigms from reference disciplines [...] the more likely they will build cumulative tradition" (Hassan & Mingers, 2018, p. 575).

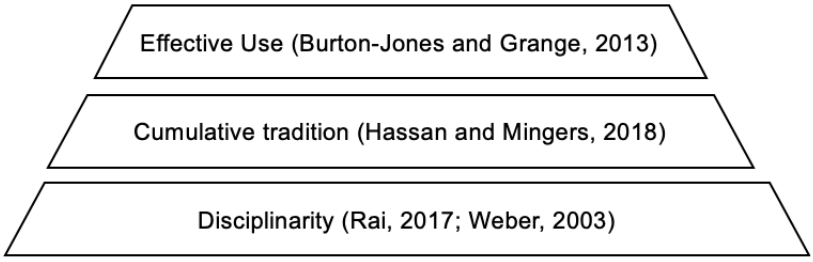

Figure 3.2: Guiding principles for emergency management scholarship in IS

3.3.2 Pursuing disciplinarity by drawing on native theories

Emergency management is admittedly a cross-disciplinary research field, which explains why EMIS inherits nonnative perspectives (Bonaretti & Piccoli, 2018b). With that issue in mind, this research addresses – with respect to EMIS scholarship – the recent call for research strategies that are "disciplinary while being interdisciplinary" (Rai, 2017, p. vi). One way to ensure disciplinarity is to draw on native IS theories (Rai, 2017). That lowers the risk to tailor the EMIS research agenda on referenced nonnative theories and, as a consequence, to follow the trail on a path of dependence towards nonnative cores.

Of course, different perspectives on what constitutes IS research exist (Weber, 2003). In that respect, we agree with the recent propositions that suggest pursuing disciplinarity means to orient IS research towards studying the *effective use* (i.e., usefulness) of a system (Burton-Jones & Grange, 2013) intended as a representational artifact (Weber, 2003, p. viii):

"We became convinced that "representation" was the essence of all information systems...By observing the behavior of an information system, we obviate the need to observe the behavior of the system it represents. We thereby avoid having to incur the costs associated with observing the represented system."

We apply this call for disciplinarity to EMIS, intertwining it with that for knowledge accumulation (discussed in the previous section). That promotes an ideal scenario in EMIS: pursuing knowledge accumulation to extend a native IS perspective.

3.3.3 Focusing on effective use

In the prior section, we mentioned that some scholars see the core of IS scholarship as focusing on the effective use of the system (Burton-Jones & Grange, 2013). Effective Use Theory (EUT) draws on the presuppositions of Representation Theory (RT) to study how decision-makers can effectively retrieve and use digital representations of real-world phenomena. System's usefulness is a function of how digital representations support decision-making (Burton-Jones et al., 2017, p. 1309). To date, there are conflicting stances towards the merits of RT, since current scholarship shows both signs of success and failure (Burton-Jones et al., 2017, p. 1329). To reconcile these mixed results, scholars called for assessing RT and achieving a final verdict about its validity (Burton-Jones et al., 2017). In that respect, EMIS research offers the context to study a major question in EUT: whether EUT remains valid beyond the traditional operational control and management contexts in which it was originally formulated. Scholars suspect that the turbulence of a chaotic environment may undermine the assumptions of RT (Burton-Jones et al., 2017, p. 1324) and, consequentially, falsify EUT. A *chaotic environment* is a context that shows "high turbulence, unclear cause-effect relationships, and acute time pressures" (Burton-Jones et al., 2017, p. 1324). Emergencies, crises, and disasters can all include chaotic environmental stressors, and thus constitute apt contexts for assessing EUT in a chaotic environment. That requires us to consider the set of "situational opportunities and constraints" (Johns, 2006, p. 386) which may change the existing functional relationships in the current model of EUT.

3.4 Theoretical development approach

In developing our contextualization of EUT for EMIS research, we follow the three-step method illustrated (see 3.3). First, we aim for *understanding* (Rowe, 2014, p. 251) by synthesizing current research on EUT, that is a preliminary step to surface the concerns about the validity of EUT in chaotic environments (Burton-Jones et al., 2017). Second, we engage in *problematization* (Rivard, 2014, p. vi) as the methodology to guide the contextualization of EUT.

Theorizing through problematization means questioning "the necessary presuppositions researchers make about a subject matter to develop the specific theory about it" (Alvesson & Sand-

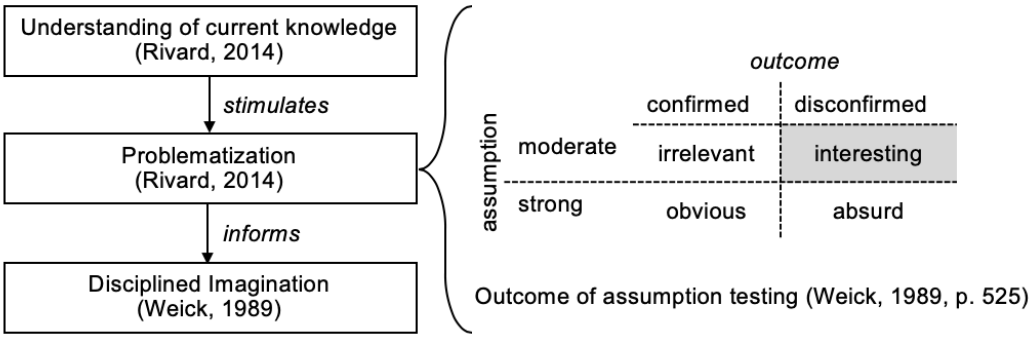

Figure 3.3: The 3-steps theorizing process

berg, 2011, p. 253). Problematization guides the analysis of the boundary conditions as a tactic for pursuing theory development through falsification (Burton-Jones et al., 2017, p. 18), a dialectical process consisting in combining different stances to revise – e.g., by extension – current formulation of EUT. The goal is to leverage the EMIS context to break the continuation of an institutionalized line of reasoning (Sandberg & Alvesson, 2011, p. 32), and advance through a coherent resolution of the anomalies. In particular, we discuss how chaotic environments change the current understanding of the EUT ontologies by questioning its accepted theoretical assumptions. For instance, what does it mean for a system to represent a chaotic environment faithfully? How do we define informed actions for ill-defined problems such as disaster response initiatives?

The idea that theory development may arise through imagination gained some consesus in IS, where scholars speculated that theories for explaining and predicting (type-IV) or for design and action (type-V) might originate from observation (Gregor, 2006, p. 633). While disciplined imagination is in part discretionary, literature discusses how to keep imagination *disciplined* and to assess the quality of the conjectures, based on whether they are *interesting* and *plausible* (Weick, 1989, p. 525). Plausibility is defined relative to the current agreement on assumptions: the stronger the assumption being disconfirmed, the less plausible the conjecture. Confirming current assumptions, instead, leads to irrelevant or obvious conjectures. Our focus is interesting and plausible conjectures, arising from rejecting moderate assumptions, which become candidates for retention and further use, such as empirical experimenting or further conjecturing.

3.5 Understanding Effective Use Theory

3.5.1 General Principles of a Representation Theory perspective for Effective Use

EUT has its roots in RT (Burton-Jones & Grange, 2013) which is central in the EUT's conceptualization of effective use and the understanding of information systems as semantic systems (Wand & Weber, 1995). RT owes its name to the conceptualization of IS as representational artifacts of real-world phenomena (Burton-Jones et al., 2017). Building on the assumption that humans and organizations have an inherent desire for information (Burton-Jones et al., 2017, p. 2), RT posits that individuals use a system to retrieve digital representations of the real-world from the system's deep structure. Thus, we call an information system a "semantic" system because it conveys meaning through a "signs' structure," its peculiarity being to be digitally instantiated into its deep structure.

Individuals leverage digital representations to enhance their understanding of reality and to take informed actions. As long as those representations are faithful, it is more efficient to learn from computerized representations than by direct observations (Burton-Jones et al., 2017, p. 4). This conceptualization of the intended use of digital representations as goal-directed is the *trait d'union* between and RT and EUT. Thus, hereafter, we call EUT what is indeed an RT perspective on effective use as described in Burton-Jones and Grange, 2013. Unlike Wand and Weber's (1995) early formulation of RT, EUT focuses on studying *how* the system works *in-use* and its role a *semantic* system, not simply system of signs to be studied *before use*, as proposed by initial work in RT.

Focusing on the system-in-use requires scholars to look beyond the sign structure – i.e., the system's *deep structure* – to study what digital signs mean to users – i.e., what they *represent* to them – and how to leverage representations effectively for taking an *informed action*. Because system use in EUT is goal-directed, effective use of the system ideally helps achieve organizational goals defined into *performance* measures. Performance depends on how informed the action is, which in turn depends on the fidelity of the digital representation. Using a system entails interacting with four components of its structure (bottom of Figure 3.4):

- *Deep structure* is the ensemble of data structures and the relational structure between them. Selecting data tokens to form the deep structure is a design choice based on a subjective understanding of what constitutes information.
- *Surface structure* is the interface between the user and the deep structure. This component allows selecting the information to retrieve from the deep structure.
- *Physical structure* is the material component that supports the interaction between deep and surface structure. To enable individuals to interact with the deep structure through the surface structure, the IS needs adequate material properties (the IT infrastructure).
- *Latent structure* is the immaterial structure of organizational culture, control, and roles (Strong & Volkoff, 2010, p. 749). The latent structure was not initially included in EUT, but Strong and Volkoff (2010) proposed it as an adaptation of Wand and Weber (1995), and RT scholars seems to have accepted it as a fourth component of the system structure (Recker, Indulska, Green, Burton-Jones, & Weber, 2019).

To achieve effective system, users need to actualize three hierarchical affordances: *user*'s transparent interaction with a *system* for retrieving faithful representations to take informed action (*task*) (Burton-Jones & Grange, 2013, p. 644). The affordance ladder of effective use (top of Figure 3.4) is hierarchical because each lower level affordance is necessary to activate a higher level one. The levels of use are defined as follows:

- *Transparent interaction* is the extend to which users can access the representations a system offers "unimpeded by its surface and physical structure" (Recker et al., 2019, p. 747)
- *Representational faithfulness* – also called *representational fidelity* – "is the extent to which someone or some group deems that a representation accurately and completely captures their perceptions of the meaning of some focal real-world phenomena." (Burton-Jones et al., 2017, p. A1)
- *Informed action*, "the degree to which a user leverages faithful representations he or she obtain from the system to improve his or her state in the domain." (Burton-Jones et al., 2017, p. A1)

The actualization of those three affordances results in *effective use*, which is a driver of *performance*: the ability to achieve organizational goals.

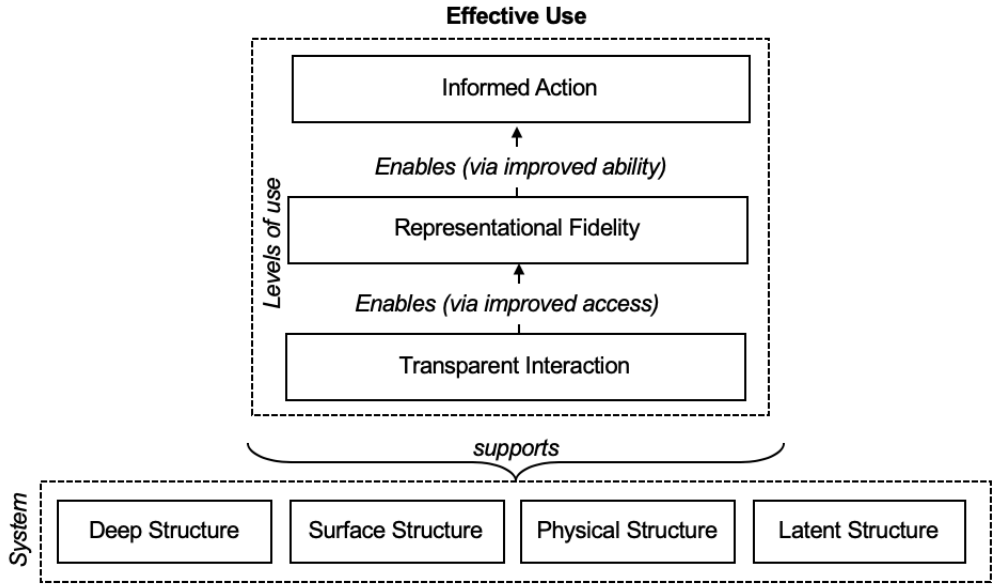

Figure 3.4: The conceptualization of *system* and *effective use* thereof

While digital representations are the core of EUT, the theory admits that other representations inform the users' decision-making as well. For instance, representations from human memory, norms, instincts also impact the system's use (Eden & Burton-Jones, 2018), and thus the decision-making. However, the core of the IS discipline remains to understand how individuals within organizations use systems to extract digital representations to cope with the task at hand (Burton-Jones & Grange, 2013).

Transparent Interaction

Transparent interaction is the extent to which a user is accessing the system's representations unimpeded by its surface and physical structures (Recker et al., 2019, p. 747). The conceptualization of transparent interaction as "unimpeded by its surface" links to concepts such as ease-of-use, usability, accessibility, and literature studying the interaction between a user and the interface (Venkatesh & Davis, 2000). For instance, how to sort the elements in a decision support system to facilitate information processing (McNab et al., 2011).

When talking about transparent interaction, it is important to remember that the surface mate-

rializes – but is not limited to – a UX interface, nor to a physical interface. Thus, *surface* refers to any affordance for interaction, for instance by speaking (vocal interface), point-and-clicking (graphical user interface), coding (through integrated development environment or console), etc.

Transparent interaction deals at the same time with more ground-level and higher-level aspects of usability. At a lower level, RT suggests that the first issue when analyzing effective use is assessing whether any interaction occurs at all. For instance, for systems that aim to engage users through push-notification via mobile devices, "transparent" interaction means primarily to prompt interaction first. An a higher level, instead, the notion reflects ideas of ease-of-use and usability.

Representational Faithfulness

Representational faithfulness – also called *representational fidelity* (Burton-Jones & Grange, 2013, p. 655) – "is the extent to which someone or some group deems that a representation accurately and completely captures their perceptions of the meaning of some focal real-world phenomena." (Burton-Jones et al., 2017, p. A1), thus reflecting "the truth, the whole truth, and nothing but the truth" (Burton-Jones & Volkoff, 2017, p. 475). A major tenant of EUT is to anchor fidelity to pragmatics, considering faithfulness an attribute of the system-in-use, as opposed to faithfulness as a *quality* of the system *before* use (Burton-Jones & Grange, 2013, p. 644). That does not mean that information quality measures are irrelevant for fidelity, but rather that information quality is insufficient to achieve representational fidelity. Thus, the *a priori* assessment of what constitutes a sufficient level of information quality is of limited use in EUT, which, instead, focuses on the ability to retrieve faithful representations as a function of the interplay between a user, system, and task *in-use*.

Informed action

Informed action is the ability to leverage digital representation in an educated manner – i.e., to make educated and representation-driven actions. Together with transparent interaction and representational fidelity, informed action actualizes system's *effective use*. It entails discerning which representations to act upon and to which degree the action leverages them. Admittedly, Burton-Jones and Grange (2013, p. 633) have coined the concept themselves, opening for possible refine-

ment of informed action. Our investigation of the genesis the term supports such current labeling.

The concept of informed action maps to early research in RT, which defined *intelligent* action as the "ability to extract meaning from symbols" (Wand & Weber, 1995, p. 207). The concept draws on computer science research, which measured system's intelligence "by its ability to achieve stated ends in the face of variations, difficulties and complexities posed by the task environment" (Newell & Simon, 1976, p. 114). While there is no single condition which is sufficient to imply intelligence, scholars concluded that a necessary condition is the "the ability to store and manipulate symbols" (p.114). In this respect, "informed action" coherently inherits from early RT scholarship the principle of symbolic representation as enablers of intelligent/informed action.

3.5.2 Effective use and performance

A major merit of EUT is to push scholars to discriminate between effective use and performance. Effective use enables higher performance, meaning their relationship is not deterministic, and effective use may actualize without driving up performance. Following a critical-realist perspective, both effective use and performance are assumed to be measurable. To measure effective use, scholars may assess compliance with intended use, where *intended use* is one that fulfills organizational goals (Burton-Jones & Volkoff, 2017, p.471). Measuring use means to discriminate among three dimensions of transparent interaction; representational fidelity; informed action. Performance, instead, consists of two dimensions: efficacy (i.e., goal attainment) and efficiency (i.e., the level of attainment given a level of input). Distinguishing efficacy from efficiency is critical to understand what "may work" in a system, i.e., as something that is efficacious but not efficient enough.

In EUT, the distinction between measures of effective use and performance serves to maintain discriminant validity between those two notions and avoid circular reasoning (Burton-Jones & Grange, 2013). Examples of circular reasoning in other theories that draw on representational approaches are common among theories of "fit" which see effective problem solving as the outcome of "good" representations of the problem space (Vessey & Galletta, 1991), which implies effective solutions originate only from "good" representations and *vice versa*.

Effective use may improve iterating through the feedback mechanism of *adaptation* and *learn-*

ing (Burton-Jones & Grange, 2013, p. 645). This mechanism applies to any element of use: system, task, and user. Adapting means transforming the system, either to enhance its ability to represent reality or to improve accessibility through the surface and physical structure. For instance, a user may adapt the physical structure of the system by buying a new monitor, or adapting its surface structure – e.g., by adding a new variable, recombining existing entries – to improve representational faithfulness. Learning improves how the user interacts with the system as-is. It involves training the users to improve their ability to leverage representations, for instance, reading the documentation to learn about the system, the represented domain, or how to leverage representations. In practice, it may be difficult to discriminate between learning and adaptation actions. Reflection-in-action, which consists in "learning from feedback" (Burton-Jones & Volkoff, 2017, p. 481), gives an account of how learning and adaptation may simultaneously and reciprocally shape each other.

3.5.3 A taxonomy of fundamental assumptions of Effective Use Theory

Before moving to the next phase – i.e., problematizing – which requires a discussion of accepted moderate assumptions, we conclude this section on *understanding* by summarizing the current assumptions in EUT based on recent literature. We sort them from more moderate to stronger assumptions drawing on (Alvesson & Sandberg, 2011), who identify five types of assumptions (*see* Table 3.2): (1) in-house; (2) root-metaphor; (3) paradigm; (4) ideology; (5) field assumptions. This taxonomy of assumptions sorts them on a continuum from more theory-specific (in-house) assumptions to more philosophical (field) assumptions.

Virtually, any assumptions may be questioned. As the right part of Figure 3.3 shows, problematization may target both moderate/strong assumptions and confirm/disconfirm any of them. However, our problematization focuses on disconfirmation of *moderate* assumptions to enable *interesting theorizing* (Weick, 1989, p. 525), by leveraging *disciplined imagination* to conjecture how to address disconfirmed moderate assumptions. While challenging moderate assumptions, we hold *strong* assumptions true to avoid conjectures that lead to *absurd*.

For instance, problematizing on field assumptions is the most ambitious strategy for theory

development but also the most likely to prove current beliefs absurd. Rejecting field assumptions from an accepted and valid paradigm threatens the credibility of the theorizing leading to implausibility. Since plausibility is a surrogate for validity when theorizing using disciplined imagination (Weick, 1989), our problematization considers "field" and "ideology" assumptions *strong* and holds them true, without conjecturing on those. We problematize, instead, on possible fallacies in moderate assumptions – i.e., in-house, root-metaphor, paradigm.

Table 3.2: A typology of assumptions Alvesson and Sandberg, 2011

Assumption	definition	examples in EUT
In-house	Assumptions that are accepted and considered unproblematic within a school of thought	Effective use consists of transparent interaction, reprsentational fidelity, informed action. More faithful representations are more useful: "users will deem an IS to be more useful to the extent it provides a faithful (i.e., accurate and complete) representation of their perception of the meaning of the focal real-world phenomena" (Burton-Jones, Recker, Indulska, Green, & Weber, 2017, p. 3).
Root-metaphor	Image associated with a particular subject matter for explanatory purposes	The nature of learning and adaptation actions to improve effective use is iterative. They are seen as loops (Burton-Jones & Grange, 2013, p. 644).
Paradigm	Ontological, epistemological, and methodological assumptions	Representations are enabling users to act in the world. Analysis of the system-in-use. Humans inherently prefer digital representations. It is in human nature to seek better ways to understand and represent the world (Burton-Jones & Volkoff, 2017, p. 59)
Ideology	Ethical and teleological assumptions	(1) The purpose of the system is to represent a domain (*ethical*); (2) an information system has one main nature and purpose, and effective use is assessed accordingly (*teleological*); (3) human behavior is goal-driven (*teleological*)
Field	Assumptions that are shared across paradigms	(1) A system is a semantic system (not a technical system to identify with its deep-structure); (2) critical-realist perspective: systems represent a (fallible) perception of a real-world phenomenon; (3) representations are always fallible, and individuals cannot ultimately retrieve an actual (i.e., completely faithful) representation of a real phenomenon (Strong et al., 2014)

3.6 Problematizing: contextualizing EUT for EMIS

3.6.1 General known limitations of EUT in chaotic environment

Preliminary research suggests that assessing EUT in chaotic environments should account for two main high-level peculiarities which distinguish chaotic from simple environments (Burton-Jones et al., 2017): (1) bounded domain knowledge; (2) time-pressure. First, users in chaotic environments have *bounded knowledge* of the forces shaping reality, and cause-effects relationships regulating the events are ambiguous. Thus, acting upon incomplete and fallible representations is often the norm, rather than the exception. Indeed, "in a process full of ambiguity, uncertainty, and time pressures...complete accuracy and consistency" are not the goals (Burton-Jones & Volkoff, 2017, p. 477).

Second, system use happens under severe time constraints and while events rapidly unfold. *Timeliness* – the extent to which an affordance actualizes in useful time – is a key environmental stressor. That means systems are hypothesized to be useful if "they support fast action to assist with the establishment of some order" (Burton-Jones et al., 2017, p. 1324).

Our problematization moves from these early considerations about bounded rationality and timeliness to understand how those environmental stressors impact current accepted assumptions and challenge EUT's theoretical presuppositions. Assessing the robustness of EUT's assumptions in chaotic environments is critical before contextualizing to EMIS.

3.6.2 In-house: time dependency of the dimensions of use

Definition of in-house assumption

In-house assumptions are those accepted and considered unproblematic, such as current definitions of constructs. The notion that effective use consists of transparent interaction, representational fidelity, and informed action is an example of in-house assumption. Moreover, adopting the definitions from prior literature for those three levels of use also shows adherence to in-house assumptions as well.

Time-dependence of use in chaotic contexts

One question to clarify when adopting the current definitions of levels use is whether they enable researchers to capture the impact of time-constraints on effective use. Recent research in EUT recognized the importance of time constraints for system use in chaotic environments (Burton-Jones et al., 2017), a theme that EMIS scholars have researched too (Yang et al., 2012, p. 770). Timeliness is critical to avert or minimize casualties and damages, which is often the high-level goal during emergency (Schryen & Wex, 2012; T. Bui & Subba, 2009; Wex, Schryen, & Neumann, 2013; McNab et al., 2011, 2009) and depends on timely action (Jiang, Yuan, Huang, & Zhao, 2012; Shatte, Holdsworth, & Lee, 2016). Thus, our problematization surfaces the importance of recasting each level of use as time-dependent, and to dimensionalize them accordingly.

To illustrate the practical importance of a time-dependent conceptualization of use in EMIS, we consider archetypal EMIS systems such as alert systems, like the SMS alert system for campus emergencies studied by Han et al. (2015). From the EUT lens, effective use of the campus SMS alerting system is conditional on whether the system can timely engage the users through SMS notification, meaning that transparent interaction includes eliciting use in the first place. Thus, to follow EUT's call for studying the system-in-use (Burton-Jones & Grange, 2013), leads to conceptualize timeliness not as a quality of the system-before-use, such as how quickly a digital representations of a threat becomes available. Timeliness, instead, has to be assessed with respect to all three levels of use. Figure 3.5 shows the three time-dependent dimensions that we identified from the literature mapping to the levels of use. What follows is a discussion of each of those.

First, a time-dependent conceptualization of transparent interaction should consider whether "seamless interaction" happens promptly and users' interaction is expedited relative to the task. Transparent interaction is prompt when it enables users to retrieve representations from the deep structure in a useful time. Because systems such as warning ones are intended to *prompt* use, timely interaction depends on *alertness*, the affordance "to notice that something that is out of place, unusual, or unexpected" (perception) in a timely manner (Weick, 2010, p. 345).

Second, we problematize on the relationship between timeliness and representational fidelity.

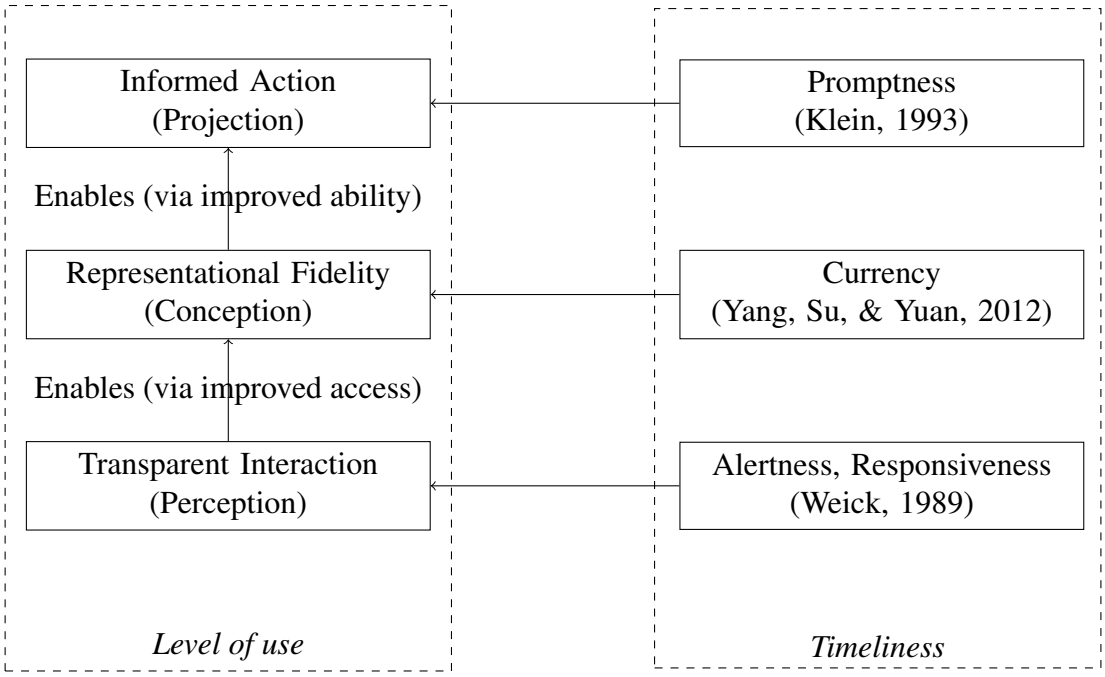

Figure 3.5: Mapping timeliness as environmental stressor to the leves of use

EM initiatives are information-intensive, and their effectiveness also depends on information quality (Bharosa & Janssen, 2010), meaning that information should be accessible and up-to-date (Osatuyi, Ding, & Chumer, 2012). Fidelity depends on *currency* (Wand & Wang, 1996, p. 92), which complements the two dimensions – i.e., accuracy and completeness – proposed in EUT (Burton-Jones & Grange, 2013). Unfortunately, achieving high levels of completeness, accuracy, and timeliness altogether is rarely an option in the aftermath of disasters. Seeking satisficing (Simon, 1955) rather than optimal representations is what decision-makers look for when operating under time constraints, as early research in rapid decision-making models of fireground commanders suggests (Klein, 1993). Thus, the value of the representational currency should always be assessed in-use, rather than from an information quality perspective.

Third, representations should enable quick action upon the retrieval of faithful representations. EUT scholars noted that, in chaotic environments, the system should presumably support "fast action" (Burton-Jones et al., 2017, p. 17), stressing that promptness in leveraging representations is key.

3.6.3 Root-metaphor: the iterative nature of learning-adaptation loops

Definition of root-metaphor assumptions

Root-metaphor assumptions are embedded within the images that scholars use to explain the nature of a phenomenon; for example, depicting an ensemble of social norms as a social "structure". Implicitly, adopting the metaphor of "structure" orients scholars to consider unity and compactness of systems. In contrast, one may consider norms (i.e., latent structure) as multifaceted. The goal of problematizing on root-metaphor assumptions is not to assess whether we can interpret them literally to derive correct conditional conjectures; in fact, these assumptions are usually false when taken literally – e.g., a *corpus* of norms does not have the material properties of a "structure". However, root-metaphors are meaningful and perhaps true when the common ground between the image and the real-world phenomenon is clearly articulated. In the next two sections, we discuss our concerns with the boundaries of current root-metaphor assumptions.

The *feedback* metaphor to depict system's morphogenesis

Our first problematization is about the use of the feedback metaphor to depict the actions for improving system's effective use. EUT posits that effective use improves through *feedback* loops of learning and adaptation actions which "reinforce each other" (Burton-Jones & Grange, 2013, p. 646). The feedback root-metaphor describes system's morphogenesis as the set of processes which change a system's structures (i.e., deep, surface, physical, latent) and their effective use (i.e., interaction, representation, action). The theory proposes a root-metaphor of the system as an adaptive entity to its environment, and adaptation as a looping, everlasting process informed by learning.

The adoption of the "feedback" and "structure" root-metaphors orients scholars to study system's morphogenesis from a systemic perspective. That means to focus on "interactions among parts of a system and between a system and its environment" (Burton-Jones, McLean, & Monod, 2015, p. 6) that actualize systems' *configurations* (O. El Sawy, Malhotra, Park, & Pavlou, 2010). Burton-Jones and Volkoff (2017) is an example of how current research conceptualizes effective

use from such systemic perspective.

The notion of transformative capability deriving from everlasting feedback loops offered theoretical ground to the idea that *improvisation* is necessary to cope with chaotic environments (Watson et al., 2013; Sakurai & Kokuryo, 2014). Exacerbating the search for malleability and minimal learning requirements, some scholars advocated for *ad hoc* systems that leverage *creative response*, a reaction "using available resources to regain the capability to meet key objectives" (Sakurai & Kokuryo, 2014, p. 7) and *improvisation*, a way to cope with dynamism, turbulence and chaos (Mendona, 2007; Njenga & Brown, 2012). Feedback mechanisms during improvisation need to cope with minimal time and resources for prototyping and testing; to use resources sparingly is key for the effective implementation of the system (Blecken, Danne, Dangelmaier, Rottkemper, & Hellingrath, 2010). This call for improvisation is popular in literature on uncoordinated disaster response through social media.

Several disaster response initiative in the last 15 years relied on crisis-related information from social media to deploy frugal systems for supporting digital volunteering, civic hacking, or local communities' groups of first-responders. Perhaps the first example is the use of MySpace for coordination in the aftermath of Hurricane Katrina (2005). More recently, scholars looked at the use of Facebook and Twitter during the 2011 Thailand Flood (Tim et al., 2017; Leong et al., 2015). Examples of digital activism using more complicated platforms include the adaptation of GitHub repositories to serve for tracking real-world issues during the 2016 Central Italy Earthquake (Bonaretti & Piccoli, 2018a). Those seem all evidence of successful improvisation-driven initiatives.

However, we clarify a would-be *jingle fallacy* (same name for different entities) when talking about chaotic environments and strategies to cope with them which may discount the appeal for the "feedback" metaphor in EMIS, at least in the edge case of improvisation. The clarification draws on distinguishing between chaotic *market* environments, and chaotic *crisis* environments.

In chaotic – or hyper-turbulent *market* environments (Nan & Tanriverdi, 2017) - organizations (i.e., companies) seek to "rapidly innovate, adapt, and reconfigure themselves to match the

changing environment" (O. A. El Sawy & Pavlou, 2008, p. 139). The ability to rapidly adapt organizational competencies is critical to maintaining a competitive advantage in chaotic/hyper-turbulent business contexts (Teece, Pisano, & Shuen, 1997, p. 516). To support adaptation, the organization should undertake fast prototyping-evaluation cycles, which help validate and refine market's requirements (R. Baskerville & Pries-Heje, 2004, p. 253). With that goal in mind, crystallized norms and routine may hinder rather than streamlining innovation, which is by definition exceptional (i.e., "not typical").

In a chaotic *emergency* environment, instead, organizations seek satisfying solutions, rather than continuous innovation to compete on the market. Emergencies are also "chaotic" – because of unclear cause-effect relationships – but not primarily because of an *a priori*, market-dictated need to reconfigure. Quite the opposite: some scholars advocated for studying emergencies as "normal accident," which show regularities, and therefore are not schemaless (Allen et al., 2014). This schema, from an Activity Theory perspective, consists of a set of activities sorted in scripts (Valecha et al., 2019). When those scripts are fluid and malleable, the system may address both emergency and non-emergency functions, thus enabling *dual use* under continuous deployment. In fact, scholars noted that "typically emergency incidents are not entirely identical to each other, but the knowledge of past incidents enables emergency personnel and commanders to recognize a similar situation and tailor their strategies accordingly by taking a course of action that experience has shown is effective and successful" (Haghighi, Burstein, Zaslavsky, & Arbon, 2013, p. 1194).

Learning and *adaptation* in chaotic environments

EUT does not delve into the nature of the learning and adaptation feedback and the impact of environmental stressors on it. Current research has yet to clarify, for instance, the multi-finality of those two actions, meaning whether similar levels of effective use can be achieved by either primarily actualizing learning, adaptation, or a combination of the two. Our review of prior EMIS literature, for instance, does not show evidence that focusing on learning may be a viable strategy to improve effective use. On the contrary, scholars noted that imposing excessive learning requirements is a barrier for digital volunteers' continuing participation to disaster response initiatives

(Valecha, Oh, & Rao, 2013), and emergent volunteer communities are more willing to commit to adaptation-driven implementations which require minimal learning (Bonaretti & Piccoli, 2018a). Despite minimal training, volunteers can carry out simple but critical tasks, such as populating the deep structure of a EMIS system for disaster response. For instance, after the Haiti Earthquake, responders needed to translate emergency SMS from Creole to English (Harnesk, 2013); in the refugee crises in Syria, manual coding of satellite imaging helped estimate the refugees' presence. Those successful initiatives, however, were adaptation-driven and kept learning at minimum.

Holding an opposite view which supports *improvisation*, some scholars highlighted the importance of learning from the environment to deviate from routine. In decision-making under time-constraints, individuals who blindly commit to existing practices and tools rather than learning from the environment may face tragic consequences, as the "dropping your tools" allegory suggests (Weick, 1988). However, as we explained earlier, expedite, extensive learning seems unlikely. The lack of professional knowledge and norms, instead, is likely to require *intensive* reflection or "ponderation" (Burton-Jones & Volkoff, 2017), which makes harder to cope with time-constraints. Training users in advance decreases their tendency to revert to inappropriate routine usage habits during crises, and less reluctant to align with the new system. Any imposition of tools may meet resistance, thus we need systems that "function during routine situations and support anomalous ones" (Allen et al., 2014, p. 430); systems should be malleable and adaptable to both emergency and non-emergency situations. Scholars recommended an "all-phases approach to EM" (Neville et al., 2018, p. 14), recognizing that systems — decisions support systems, in particular – that are occasionally or first-time implemented during emergencies are unlikely to be successful.

3.6.4 Paradigmatic assumption

Definition of paradigmatic assumption

The problematization of paradigmatic assumptions challenges the current understanding of ontological, epistemological, and methodological assumption (see Table 3.2). Of the three assumptions we problematize on, a violation of a paradigmatic assumption is the most likely to generate new

research questions (Alvesson & Sandberg, 2011, p. 255). In particular, we problematize about: (1) the meaning of performance in EUT, and the idea of measuring effective use as the extent to which the system enables "the achievement of broader organizational goals" (Burton-Jones & Volkoff, 2017, p. 471); (2) the adoption of a "performative" perspective for studying effective use.

Defining performance in EMIS

To define performance as the attainment of organizational goals assumes that organizations intend to pursue goals that comply with the EUT's notion of effective use. That assumption is plausible only if organizations themselves can discriminate between a "style of use" and effective use, or between the attributes/qualities of the system-before-use and the outcome/effectiveness of the system-in-use, and calibrate organizational goals accordingly. For instance, setting organizational goals on the improvement of use quantity, usability, satisfaction (Ives, Olson, & Baroudi, 1983), is problematic from a EUT perspective. Measures of the quantity of use of platforms for emergency response such as "[during the 2011 Thailand flood Twitter use] had increased 20 percent within 1month" (Tim et al., 2017, p. 212), or measures of "user satisfaction" (Yang et al., 2012, p. 781), are also measures of styles of use which overlook how the system impact performance.

A style of use explains *how* users engage with the system but not how effectively the system supports the task at hand. The ability to discriminate the style of use from effective use is a non-trivial methodological aspect. For instance, ethnographic or interpretativist approaches to infer meaningful performance measures may bias the analysis and reflect the organizational focus on styles of use, rather than effective use.

Member of organizations, particularly ephemeral, emergent ones (e.g., volunteer groups), may fail to meaningfully define their own organizational goals from a EUT standpoint, such as a "do-good" mission to guide the development and evaluation of the system. We illustrate one limitation of an ethnographic approach with an example from our experience with campus SMS emergency systems in the US.

For each public campus, government guidelines mandate the implementation of systems for mass-distributing emergency alerts via different channels in the presence of a verified threat (U.S. De-

partment of Education, 2016). According to government guidelines, the effectiveness of the system is a function of how timely the notifications are distributed. However, from a EUT perspective, that is a measure of the system *before-use*, since it ignores how the users (i.e., the alerts' recipients) use the system (e.g., to take counteractions for protecting themselves). Now, suppose that the researcher elicited definitions of effective use of an alerting system through interviews with the employees of an emergency preparedness office. Those definitions will likely revolve around adopted government guidelines, such as "the system is effective if emergencies are timely notified;" which does not fully capture the notion effective use from a EUT perspective. From the users' standpoint (i.e., the campus community), the ultimate goal is to protect themselves. Besides alerting would-be victims, an alerting system should offer recommendations for action (Reuter, Kaufhold, Leopold, & Knipp, 2017, p. 2198). Thus, prompting compliance with authorities' guidelines for effectively protecting themselves maybe a more plausible measure of *performance* than timely notification in itself. Similarly, effective use means to provide digital representations that enable such compliance – e.g., actionable indications of how to avoid the threat. In that respect, timeliness and accuracy are essential, but not the only determinants. At the same time, choosing compliance as a measure of performance is a theory-driven conjecture which does not surface from existing organizational norms, and is unlikely to emerge ethnographically without drawing on EUT.

Performative *versus* ostenstive measures of effective use

The second target of our problematization is the current performative perspective on effective use and its epistemological implication. We call the current conceptualization of effective use "performative" because it focuses on the action and enactment of affordance to understand its "dynamic and contingent socio-material configurations" (Orlikowski, 2007, p. 815). Thus, measuring the level of informed action always depends on a "doing". On the other side, *ostensive* (Latour, 1984, p. 272) perspectives assume that reality exists "independently of human action or interaction" (Orlikowski, 2007, p. 815). The ostensive perspective and the critical-realist epistemology, which EUT adopts (Burton-Jones & Grange, 2013, p. 640), share a similar view of reality. That means further clarification is needed regarding the epistemological nature of "informed action," and whether its

performative nature is admissible under a critical-realist perspective.

Challenging a paradigmatic assumption about the nature of informed action impacts the epistemological value of assessing the system's usefulness performatively through the actions that users perform. Perhaps this concern yet to emerge from prior EUT literature because researchers have been focusing on non-chaotic environments. In simple operational contexts, the gap between projection and execution of an action is narrow. For instance, an online shop tends to ship orders (action) upon retrieving a list of purchased products (representation). In chaotic environments, however, even simple automation process may be hampered by physical obstacles, excessive workload, inadequate training, system problems, external agents, and the like, leading to poor executions. This issue has been raised, in part, by Burton-Jones and Volkoff (2017, p. 470) in the complex context of electronic healthcare systems. That raises the question, for instance, of whether scholars should infer ineffective use from poor execution of potentially well-projected actions. Thus, considering *action* as a dimension of use shows an epistemological limitation when contextualizing EUT to EMIS.

3.6.5 Ideology assumptions

Ideology assumptions refer to the political, ethical, teleological aspects of the theory. In this section, we propose a problematization of ethical and teleological assumptions for completeness. Nonetheless, we avoid conjecturing on ideology assumption as that would exceed the scope of this research.

Ethical assumptions

Challenging of *ethical* assumptions is an effective tactic to derive moral dilemmas from EUT. For instance, are faithful representations always attainable and desirable? Or are there circumstances under which less-than-faithful representations are preferable? Is representational fidelity always the best approach to increase performance? We acknowledge the answer maybe "no" to each one of those questions. Thus, we shortly illustrate how ethical concerns may impact design decisions in EMIS, yet without the pretense to be exhaustive, since conjecturing on ideology assumptions is beyond the scope of this manuscript, and would lead to "absurd" conjectures, as we explained

earlier.

One may design an alert system to persuade/manipulate users to comply with safety guidelines, yet leveraging subjective norms (Han et al., 2015) rather than representational fidelity. Moreover, there are cases where representational fidelity is straight undesirable. For instance, during the 2016 Brussels Terrorist Attack, the police called for a "radio silence" on Twitter, to avoid unwitting support to terrorists at large for locating police units. In response to the police's call, users started twitting pictures of kittens and puppies to intentionally spread digital rumor and hinder the retrieval of accurate information from social media (Bonaretti, 2018).

Another reason why this assumption maybe not tenable is that, even when working for the public good, organizations compete from resources. For instance, NGOs compete for funding, and may be unwilling to share information (Wakolbinger et al., 2013).

Teleological assumptions

Another matter of concern is the teleological assumption stating that information systems have one primary nature and purpose, and effective use is defined accordingly (Burton-Jones & Grange, 2013, p. 634). Research in EMIS, instead, suggested that systems should be designed for *dual-use* (Allen et al., 2014), meaning to support both routine and crisis processes. At the current stage, it is unclear how EUT may accommodate dual-use and dual-function design principles.

Another issue is the nature of dual-*function* that system may serve during emergencies. For instance, a system may serve both a *substantial* function, such as alerting the population, and a *symbolic* function, such as signaling that the government is taking countermeasures to address a crisis.

3.6.6 Field assumptions

Field assumptions are those shared across theoretical schools, such as the philosophical perspective. For instance, the critical-realist perspective underlying EUT (Burton-Jones & Grange, 2013, p. 640) belongs to this set of assumptions. They are difficult to identify because common consensual grounds are less likely to be debated as considered "obvious."

Another field assumption is that systems can be described as a structure. We recall that, in

the first section of this manuscript, we defined a system as consisting of four main structures: deep, surface, physical, and latent. Further research argued that the system structure interacts with the social structure Eden and Burton-Jones (2018). However, in EMIS, Activity Theory, and the conceptualization of systems as networks of actions/activities – rather than structures – seem to be more popular (Allen et al., 2014; Valecha et al., 2019; Chen, Raj Sharman, Raghav, & Shambhu J, 2008).

One advantage of focusing on the idea of system as a structure is to better inform the discourse on resiliency, which some scholars depict as the first concern in EMIS (Hans Jochen Scholl & Patin, 2014). When thinking about a system as a structure, there is a tendency to define users by the part of the deep structure they access. The artifact, through its use, defines the function (Hans Jochen Scholl & Patin, 2014, p. 38). One implication is that, for EUT, the resiliency of a function primarily depends on the resiliency of its supporting structure. That means maintaining the structure functional enables the material properties of information systems to provide an actionable space that patterns organizational practice (Seidel, Chandra Kruse, Szkely, Gau, & Stieger, 2018). The popularity of social media seems to support in part this conceptualization of system as a dispositional affordance.

Drawing on "action", instead, defines users by functions, which may help think of emergency response in inter-organizational or emergent terms. The "action" perspective may be more effective in capturing contexts where roles are dynamically redefined while the emergency unfolds.

3.7 Conjecturing: Theorizing using disciplined imagination

In this section, we present our set of plausible conjectures to respond to the violations of moderate assumptions that we surfaced in the prior section on problematization (Table 3.2). Theory development through imagination consists in drawing on mental experiments to assess the validity of current assumptions (Weick, 1989, p. 519). Thus, when using disciplined imagination, we evaluate conjectures adopting *plausibility* as a surrogate for validity (Weick, 1989, p. 525). Plausibility is derived based on existing knowledge. A conjecture is plausible when, moving from EUT assumptions, we can draw conclusions which comply with empirical evidence from prior studies.

However, our problematization shows that is not always the case: some of the conjectures that we could draw from current EUT's assumptions are implausible in light of EMIS research findings. When a current assumption in EUT turns out to be implausible, we leverage disciplined imagination to inductively refine moderate assumptions of EUT based on evidence from EMIS research. Refining the assumptions enables the formulation of new research propositions to inspire future research in EMIS. Table 3.3 presents a list of possible testable propositions.

Table 3.3: Research propositions

Stressor	Conjecture
time-constraint	The levels of use are time-dependent constructs. A measurement tool can be developed to assess assess their validity accordingly.
time-constraint	To cope with time-constraints effective use is more likely to increase through adaptation-driven actions. Learning barriers should be minimized progressively with increasing levels of time-constraints.
methodological	Organization's members may be unable to distinguish effective use from performance. Researchers should conjecture to achieve such discriminant validity when it is not reflected in existing organizational structures. Prior recommendation for interpretative researchers to engage in an "intimate dialogue" with practitioners should account for such limitation.
philosophical	Performative conceptualizations of system use, such as "informed action" are implausible within a critical-realist perspective.
ontological	Situational awareness is a valid level of use.

3.7.1 Conjecturing on in-house assumptions

The problematization of in-house assumptions shows that the current dimensions of the levels of use (i.e., transparent interaction; representational fidelity; informed action) overlook the role of timeliness in achieving effective use. That calls for redefining both EUT's levels of use and their dimensions as time-dependent. This aspect has a major implication for developing measurement tools for effective use in time-sensitive contexts.

Coherently with the EUT's epistemology, the design of time-sensitive measures should capture time-sensitive characteristics of each level of the system *in-use*. That means time-dependency is a constitutive dimension within each level of use (see "effective use" box in Figure 3.6). We provide examples of time-dependent question items for scale development in Table 3.4.

Table 3.4: Proposed question items to measure time-dependency of use

Construct	time-dependent question item
Transparent Interaction	When the system alerts me, I react right away
	I have access to the system at all times
	The device I access the system from is always working (e.g., mobile device is charged, has signal, etc.)
Representational Fidelity	The emergency is active when I am notified through the system
	The delay between the digital representation and the actual status of the real world is negligible
Informed action	I can act timely upon the digital representation

The approach to contextualize EUT draws on Hong, Chan, Thong, Chasalow, and Dhillon, 2014 as depicted in the nomological network represented using solid-boxes in Figure 3.6. We contextualize EUT by adding time-dependent dimensions to each of the three levels of use: (1) *responsiveness* indicates the readiness of the system to users' input, or *alertness*, which indicates the user's readiness; (2) *currency* entails the ability to state-track the domain and to store up-to-date data structures to represent is current state; (3) *promptness* is the rapidity of accessing and leveraging representations. The contextualization results in adding the dimensions depicted using the dashed-boxes in Figure 3.6. The dotted-boxes, instead, represent competing ways to contextualize EUT and account for context-specific stressors such as time-dependency.

For instance, a previous study of how time constraints impact usage built on Cue-Summation Theory and interpreted time constraints as a moderator (i.e., *time pressure*) between use of an emergency dispatch application and performance (McNab et al., 2011). The study found that higher information quality (higher number of cognitive cues) has the same positive impact on performance (the ability to respond to incidents) regardless of time pressure. While also highlighting the importance of time-dependent measures of use, we excluded similar conceptualizations of time-constraints (e.g., time as moderator or mediator) since they do not situate the levels of use in (time-constrained) *use*, but rather conceptualize the levels of use as entities that are measurable independently than their time-constraints. Similarly, we have not considered additional antecedents

of effective use, or outcome of performance that future research may include.

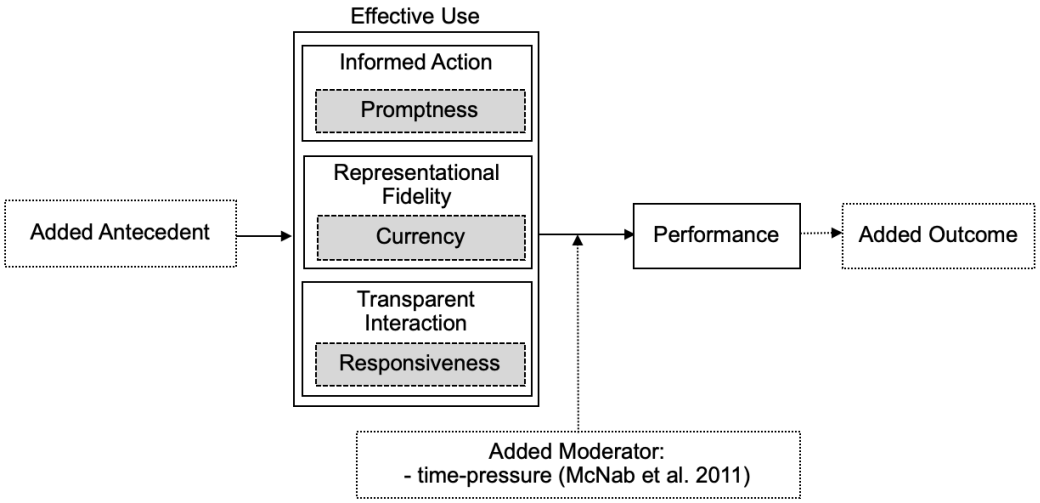

Figure 3.6: Contextualization of the EUT model to chaotic environments

3.7.2 Conjecturing on root-metaphor assumptions

In our problematization, we introduced the concepts of dual-use of EMIS, and designing EMIS for "normal accidents." In this section, we attempt to scale the notion of *intended use* from EUT to the attainment of dual-use, and how to achieve it effectively.

Dual-use means that users *learn* how to use the system effectively while serving routine activities, yet can adapt the system to for coping with emergencies easily. In EUT terms, dual-use allows users to learn, which increases professional knowledge, and in turns enables effortless "reflection-in-action" learning styles (Burton-Jones & Volkoff, 2017, p. 476) that lessen additional learning requirements for using the system effectively in a chaotic environment. Rather than pondered, discernible "learning", *reflection-in-action* (Burton-Jones & Volkoff, 2017, p. 476) is intermingled within system's use to achieve short term goals more effectively. Because reflection-in-action is calibrated on short term goals, users who adjust reflection in response to feedback, do not do so "deterministically" (Burton-Jones & Volkoff, 2017, p. 481).

While some scholars assume that users are "goal-oriented" (Burton-Jones & Volkoff, 2017, p. 469), which means system use is finalistic, the non-deterministic adaptation of system's use as a result of reflection-in-action should lead to consider system use as rather *goal-directed* (Burton-

Jones & Grange, 2013, p. 633). Because the distinction between goal-oriented learning and goal-directed reflection-in-action may be subtle, we propose two criteria to discriminate among the two. The first is *time*. Reflection-in-action occurs while using the system and within a limited time-span. Learning, instead, involves a ponderation which extends beyond reflection while using the system. The second criterion is looking at the impact of reflection and learning on the latent structure. In the case of reflection-in-action, users to deviate from existing norms without adapting the latent structure overall. However, the more those deviations become persistent and "learned," the more they an adaptation of the latent structure becomes likely.

The feedback metaphor captures learning as a goal-*oriented*, long-term process of comprehending the current configuration of the system; but that process is distinct from reflection-in-action as a time-constrained, goal-*directed* function, which is key to enable effective dual-use (Figure 3.7). Thus, we conjecture that if dual-use was the design objective, then enabling reflection-in-action would be the primary concern when entering a chaotic environment. This clarification regarding the role of learning and reflection-in-action differs from other approaches mentioned in our problematization that pivot on the notion of *improvisation*.

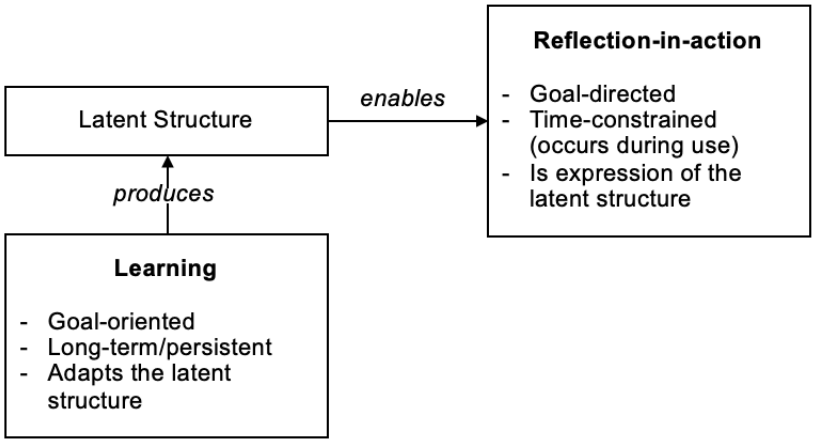

Figure 3.7: The relationship between learning and reflection-in-action

For example, the dual-use of social media is enabled by the system's malleability, which allows user to use social media effectively by adapting the deep and surface structures (e.g., by posting crisis-related information) while minimizing learning (i.e., the adaptation of the latent structure).

The adaptation or those structures provide an organizational space for a latent structure that has already been "learned" as peculiar to the socio-technical role of social media; for example, the belief that social media may support collaborative action.

Moreover, perceived ease-of-use is higher because of the familiarity with the system in routine environments, which increases the intention to use (Venkatesh & Davis, 2000), giving an account of why, and more so under time constraints, individuals are reluctant to undergo learning efforts. The idea that deploying systems specifically during crises is flawed (Allen et al., 2014, p. 430) is explained, in EUT terms, by the overhead on effective use of learning actions, *viz* adapting the latent structure, under time constraints.

To explain why adaptation of the latent structure is laborious, especially for public organizations that operate in EMIS, we draw on prior research that investigated the homeostatic tendency of public organization to preserve their latent structure "as-is" (Silva & Hirschheim, 2007). While this homeostatic tendency may not affect frugal, emergent organizations, it does constraint public organizations that typically coordinate EMIS initiatives. In that respect, prior literature highlights how system-specific latent structures may explain public organizations' reluctance to use social media (Shan et al., 2017), which instead some emergent organizations rely on.

3.7.3 Conjecturing on paradigmatic assumptions

The problematization of paradigmatic assumptions surfaced two problems with nontrivial epistemological implications: (1) defining performance upon organizational goals; (2) adopting performative perspectives of use.

Regarding the definition of performance, scholars need to critically assess whether organizational goals are apt measures of performance from an EUT perspective, meaning that organizational goals are distinguishable from effective use. Choosing an apt measure of performance implies the researcher's active role in scrutinizing plausible definitions of performance. This effort differs from studying how systems might fulfill not formalized – and yet still useful – functions (Meesters & Van de Walle, 2014). It also differs from interpretative perspective on the enabling role of technologies (Leong et al., 2015) in EMIS. The researcher should identify a space of per-

formance measure that plausibly depend on effective use. In Table 3.5, we propose five principles for assessing the plausibility of performance measures.

Table 3.5: Guiding principles for conceptualizing performance

principle	definition	Example in EUT
Manipulability	Performance is attributable as much as possible to effective use	While "saving lives" may be a plausible measure of performance, it is often a candidate for rejection because because it cannot be easily manipulated, or it is unethical to do so. It is not concrete enough to be a performance indicator.
Distance	Performance is distant enough (e.g., semantically) from effective use to avoid circularity	Usability, ease-of-use, and constructs that describe a "style" of use are semantically equivalent to effective use. Performance should not be derivative of effective use.
Dimensionality	Performance can be measured along efficacy and efficiency	EUT assumes performance is bi-dimensional. Researchers should discriminate among those dimensions – even if only theoretically.
Concreteness	Performance is sufficiently concrete to be understood and acted upon	The measure has practical relevance for members of the organization and links to well-defined tasks. For instance, *do-good* is unlikely to satisfy concreteness it describes a general attitude rather than a specific task.
Topology	The ontology maps consistently to its counterparts in cross-related research	Due to research-methodology (e.g., case-study) and the relative uniqueness of each disaster – which may constitute context in itself (Johns, 2006, p. 388) – similar constructs may adopt inconsistent parameterizations. This hinders cross-referencing and should be kept at minimum.
Good reason	Performance measures should map to positive ethical instances (i.e., in compliance with ideology assumptions)	Measure of performance that involve *manipulation* to prompt action may be unethical. In principle, EUT rejects system with manipulative intent since the goal of a system is to stimulate action upon faithful representation

Second, we propose to adopt an ostensive definition of effective (i.e., *situational awareness*) to cope with the epistemological that the notion of "informed action" raises from a critical realist standpoint. In line with prior research on use, we propose to exclude action from system use (Richard P Bagozzi, 2007), as it helps cope with the limitation that "effective use may fail to

generate the outcome if another mechanism overrides" (Burton-Jones et al., 2017, p. 469). Thus, we conjecture that effective use should include only *projections* of actions, which are cognitive tasks, as opposed to informed actions, which are performative ones. When using a system, the ultimate goal is to translate a digital representations into a mental ones, which becomes the ground for action. Based on our literature review, the construct of situational awareness is the best candidate to connect EMIS scholarship to a theoretical basis for studying action projection under time constraints. The concept of situational awareness as "action projection" may scale to fit the edge cases of systems' use that seek automation, for example through AI, in emergency management. In EUT terms, automation would be the ability of a system – perhaps an "intelligent" system – to effectively mirror a responsible agent's decision-making process. Defining what means to be a "responsible" agent is a design decision which reflects social and ethical criteria from government agencies, emergency professionals, and the like, that belong to the latent structure of the system.

To summarise, the conceptualization of the levels of effective use focuses on situational awareness (projected action) instead of informed action. In turn, performing the projected action impacts task performance, which is a function of effectiveness (whether the action fulfills a purpose) and efficiency (how it fulfills the purpose compared to other possible actions). Recasting effective use on projection enables scholars to distinguish when downfalls in performance are independent of the user's ability to use the system effectively, for instance because they are caused by environmental impediments which hampers informed action. That differs from the received view so far which, instead, sees the assessment of effective use based on two, performative measures of effective use : "assessment of behavior, or outcomes" (Burton-Jones & Straub, 2006, p. 235).

3.8 Discussion and Implications

The primary objective or our work is to proposes a theoretical perspective to pursue disciplinarity and knowledge accumulation in EMIS. Building on the idea that use consists in retrieving digital representations of a real-world domain, we surfaced the methodological and theoretical issues that exist when contextualizing EUT to chaotic environments. In this section, we provide an answer to our research question about the validity of EUT in chaotic environments. Moreover, we discuss

the implications of our theory development for EMIS and EUT scholarship.

3.8.1 Implication for EMIS scholarship

The pursue of disciplinarity and unification, which some scholars advocate for (Rai, 2016), builds on a debated assumption within the IS community: that research directions should seek the consensus of the scientific community. Proponents of anarchic epistemological positions, instead, disagree with the idea that seeking a holistic perspective has any value whatsoever (Treiblmaier, 2018). We see a holistic approach as helping prevent EMIS research from compartmentalizing in disconnected research silos, which hinders rather than facilitates the emergence of new ideas (Hirschheim et al., 1996, p. 5). Organizing prior research under EUT may help uncover its merits in understanding emergencies as socio-technical problems. In our presentation of EUT, we explained how this theory is developed with the intent to reorient IS scholarship on the investigation of system use; thus, its assessment in EMIS may be refreshing for research on organizational issues in chaotic environments such as collaboration, communication, and coordination. In fact, scholars have yet do define how a representational approach to study those questions would look like. Focusing on system use, a native IS perspective may study technology-mediated organizational phenomena as problems about systems' interdependencies-in-use (Karsten, 2003). That suggests EUT may provide socio-technical explanations to organizational phenomena that scholars have so far investigated from nonnative theoretical perspectives.

3.8.2 Implication for EUT scholarship

This research extends EUT by refining the definition of effective use to account for time-related environmental stressors. The goal is generalizing and extending theory to maintain the current level of explanatory power – a pursue of both *extension* and *intension* as per Burton-Jones et al. (2017, p. 1315). However, this conceptualization of effective use as a time-dependent affordance ladder now awaits empirical validation. One way to support to the plausibility of our conjecturing, would be through the development and validation of a scale following our prescriptions. Scholars may test the goodness of fit of a scale of effective use where *effective use* represents a second-order construct, which depends on transparent interaction, representational fidelity, and situational

awareness. In doing so, the dimensionalization of each of the first order constructs (the levels of use) should include time-dependent items. The translation and assessment of the measurement model using a pure variance approach is useful to reveal would-be issues in its specification (Burton-Jones et al., 2015, p. 672).

While our strategy for theorizing has been to generate interesting conjectures from disconfirmed assumptions, reasoning on obvious conjectures may also lead to valuable conjectures (Weick, 1989, p. 526), in particular when confirming *strong* assumptions – i.e., ethical and field. In our problematization, we gave an account of how ethical assumptions have non-trivial implication in a design of a system to decision-making . For instance, developers may devise systems which aim at persuading individuals to act, rather than creating the best conditions for them to act upon digital representations. Debating ethical assumptions when applying EUT to EMIS is critical because of the possible impact on public health and human well-being.

3.8.3 Implication for IS scholarship

Conducting IS research in emergency management and adopting crises as research context is beneficial for the IS field overall. The value of looking at fast-evolving scenarios is to offer suitable platforms for rapid testing (Weick, 2010). Focusing on a crisis as the observational unit narrows the time-space and limits the confounders at play. Crisis events may facilitate controlling for variability because of their more self-contained nature: "if you watch a compact, specific, short event then you can grasp most of it with relatively few factors" (Weick, 2010, p. 537). That means EMIS scholarship should seek to formulate concepts that scale to phenomena that, while not necessarily disaster-related, share similar environmental stressors with emergency scenarios (e.g., reputation crises in the industry).

For instance, because social media exacerbates the human tendency to seek information during disasters (Winerman, 2009), crises are ideal environments for looking at rumor-propagation phenomena. That should not distract EMIS researchers from pursuing research paths that contribute to the core of the IS discipline. From Weber (2003, p. v–ix), there are three aspects to understand whether a line of research in emergency management is contributing to the core of IS.

3.8.4 Implications for practice

EUT advocates for redirecting current scholarship to analyze systems in-use. While a thorough review of manifold document types produced by government and industry (i.e., *grey literature*) is beyond the scope of this research, we illustrated using an example about campus alert systems how theoretical perspective instills into grey literature (e.g., U.S. Department of Education, 2016) and orient practitioners' perspectives of thinking about the performance of the systems they use. Therefore, adopting an information quality (system-before-use) as opposed to an effective use (system-in-use) perspective has tangible practical implications on real-world system implementation. In this respect, Ghoshal, 2005 noted that scholars tend to underestimate the influence of scholarly knowledge on real-world practices. Studying emergency management from a EUT perspective may offer new theoretical lenses to rethink current government guidelines and policy.

3.8.5 Implication for scholarship on social media for EMIS

While results of effective use of social media for disaster response are still inconclusive, some scholars assume that "extracting information from social media should make sense and be beneficial for crisis management" (Stieglitz et al., 2018, p. 6). EUT may help articulate what it means to use social media effectively, and how scholars expect social media analysis to improve the performance of EM initiatives. A unifying EMIS perspective will need to be applicable to studying digital interaction in the social space during disasters, and explain how to leverage crisis-related information from social media. We expect EUT may meaningfully apply to this area of investigation. For instance, while research on social media has been focusing on connective actions on social media, it has only recently started to question *how* social media use enables actualizing connective action (Vaast et al., 2017). In EUT terms, connective actions are a plausible intended use for social media to cope with disasters, but research that links the actualization of connective actions to performance measures has yet to emerge.

Scholars have repeatedly advocated for harnessing crisis related data from social media to inform disaster response initiatives (Mukkamala & Beck, 2016; Tim et al., 2017), especially when urgent response is paramount (Valecha et al., 2013). Twitter, in particular, has magnetized scholarly

attention, and government agencies are institutionalizing social media analysis initiatives. For example, the American Red Cross has a dedicated Social Media Digital Operation Center for Humanitarian Relief. Moreover, anecdotal knowledge – which echoes in scientific literature (Acar & Muraki, 2011) – corroborates the belief that social media are a useful source of information during disasters. A EUT perspective may help articulate how social media can effectively support disaster response initiatives.

3.9 Limitations

Our research highlights two sources of fatal criticisms for contextualizing EUT theory to EMIS. First, by drawing on EUT, our research remains vulnerable to the criticisms against RT and representational views in general. While a final verdict on the validity RT has yet to be reached (Burton-Jones et al., 2017, p. 22), some scholars lean towards philosophical positions that may be irreconcilable with RT's critical-realist perspective. For instance, socio-materiality perspectives contend that there is little value in studying the ability of information systems to establish consistent connections between digital signifiers, a real-world domain, and its digital representation (Orlikowski, 2007, p. 816).

The second criticism challenges the value of pursuing an EUT line of research in EMIS. This research is valuable insofar as the scholarly community agrees on the importance of scrutinizing a type-IV theory to orient and unify EMIS scholarship. One attribute of type-IV theory is the ability to generate testable propositions. However, scholars argued that knowledge accumulation is possible through a one-step process of "understanding", consisting in developing *applicative knowledge* (Hirschheim, *forhcoming*) without drawing on a "grand theory".

3.9.1 Limitation of EUT

Some scholars, instead, criticized the focus on studying how technology supports EMIS as delusional. They recommend, instead, to investigate the whole crisis response infrastructures (Hans Jochen Scholl & Patin, 2014) that the information system supports. A crisis response infrastructures may consist of multiple *interlinked* and *related* artifacts (Harnesk, 2013). "Interlinked" means that they maintain distinct social behavior while supporting collective functions. For in-

stance, coordination of first responders through social media is an example where the infrastructure does not interfere with the participating systems, and the limitations of their interdependence remain. To implement infrastructures based on interlinked artifacts, it is critical to scrutinize those that embody the desired standards.

This perspective is particularly useful in EMIS because it stresses the human factor and the situatedness of information use, which happens within the infrastructure. While information systems literature acknowledges those factors, we attempt to bring the two perspectives together. One radical difference is that while EUT strives for performance (Burton-Jones & Grange, 2013), thinking in terms of information infrastructures, instead, leads to focus on *resiliency* (Hans Jochen Scholl & Patin, 2014, p. 44). Moreover, the information infrastructure is part of other structures, such as the social one.

3.10 Conclusion

The increasing relevance of technology in supporting disaster response initiatives presents IS with the opportunity to enhance the societal impact of its scholarship. Our research examined how to empower IS researchers with a theoretical perspective to engage the discourse in IT-enabled disaster response from a socio-technical angle. That means thinking about the ability of a system to provide a faithful digital representation of a chaotic environment to enable quick decision-making under time-constraints and high uncertainty. Our research discussed how EUT scholarship can contribute to address this area, and what are some key elements of EUT to rediscuss. In particular, we proposed an ostensive measure of effective use (situational awareness) and a deeper understanding of the impact of time-constraints of the level of use and on actions to improve effective use. We believe our research offers a perspective to reorient the investigation effective use of technology in emergency management towards research paths that enable stronger contributions to the core of EMIS.

CHAPTER 4
EFFECTIVE USE OF CAMPUS EMERGENCY ALERT SYSTEMS

4.1 Introduction

Since the 1990 Clery Act (Clery Act, 20 U.S.C. 1092), public universities are required to disclose information about crime incidents on campus and their security policy. The purpose of such mandatory reporting is to increase *awareness* regarding safety issues, and enable campus community members to take countermeasures for protecting themselves. Initially, enhancing awareness was an asynchronous task. It consisted in framing members' expectations based on information about past safety threats. Nowadays, the increasing pervasiveness and ubiquity of information technology (IT) (e.g., smartphones) (Yoo, 2012) enables emergency communication to be situated in time, and to make awareness *situational*: countermeasures can be taken synchronously upon real-time communication of an ongoing threat. For US universities, emergency communication duties include the real-time dissemination of *timely warnings* or *emergency alerts* in the presence of a verified immediate threat (FEMA, 2017). To disseminate emergency messages, campus Emergency Operation Offices adopted *Emergency Alert Systems* (EAS) software for multi-channel emergency notification. EAS are system for mass-sending of emergency alerts through email, SMS, social media, intranet. Our goal is to look at how EAS are currently used to respond to the question: How to define and to measure the effective use of an EAS?

Multi-channel communication increases the pervasiveness for alerts, and to reach a large number of campus community members. Timeliness is also critical to enable the recipients to counteract and protect themselves within a useful time. Thus, regulatory guidelines stress the importance of timely communication of ongoing threats (FEMA, 2017). However, this practice-oriented perspective downplays the assessment of the EAS effectiveness *in-use* (Burton-Jones & Grange, 2013). Conversely, the design objective is rooted in socio-political circumstances. The current EAS implementation has not focused on information systems (IS) perspective for studying EAS in-use.

The first section of this article illustrates the socio-political drivers of the current EAS' imple-

mentation. In particular, we scrutinized two events that lead to nowadays EAS implementation: the 1990 Clery Act, and the 2007 Virginia Tech Shooting. Drawing on Punctuated Theory (Silva & Hirschheim, 2007), we interpret those as *revolutionary* events that drove IS implementation strategies. Punctuated Equilibrium posits that implementation strategies in public organizations remain crystallized until a revolutionary event occurs which shake the existing organizational social structure[1]. This research articulates the benefits of rethinking of EAS from an *effective use* perspective that studies EAS *in-use* (Burton-Jones & Grange, 2013). This perspective aims to capture how users interact with the system, and what it means to do so effectively (Burton-Jones & Grange, 2013). Instead of thinking of performance as timeliness and pervasiveness of the emergency communication (FEMA, 2017) focuses on measures of the system's quality *before use*.

The second part of our paper focuses on measuring the effective use and performance of the EAS in-use. We scrutinized a plausible measure of performance from prior IS literature in EAS' use. Some scholars identified *compliance* with the content of an alert message as a plausible conceptualization of intended use (Han et al., 2015; D. Fisher, Putzke-Hattori, & Fischbach, 2019). However, extant research has yet to address how system's *in-use* – rather than its qualities *before* use – may increase performance. To study the relationship between system's *effective use* and *performance*, we draw on a representation theory perspective of effective use: Effective Use Theory (EUT) (Burton-Jones & Grange, 2013). EUT serves as a Type-V theory for guiding the evaluation and the design of the EAS (Gregor, 2006). Therefore, we adopt EUT with a *prescriptive* intent (Walls et al., 1992). The dimensions of *effective use* serve as meta-requirement (i.e., design goals) to pursue when implementing the EAS. This use of EUT is under-explored both in EUT and EAS domains.

To inform this research we combined three bodies of knowledge: (1) a diachronic socio-political analysis of EAS implementation and its awareness-oriented design; (2) research in effective use and the system's role in supporting situational awareness (Bonaretti & Piccoli, 2018b;

[1]Prior literature (e.g., (Silva & Hirschheim, 2007) adopted the term "social deep structure"/"deep structure" to define what we simply call "social structure". We avoid using the term "deep structure" to avoid confusion with the term "deep structure" that we introduce later on in this manuscript to describe a component of the information system

Bremhorst, 2018); (3) grey literature[2] from the practitioners' world (FEMA, 2017).

We combine those three research streams to develop a measurement instrument for assessing the effective use from a EUT perspective. Pivotal to our measure is the construct of situational awareness, and seeking situational awareness oriented design in IS for emergency management (Yang et al., 2012). Our measurement instrument has two merits: (1) to enable the assessment of EAS in-use across three levels of use; (2) to enable the assessment of each level of use as time-dependent affordances. By discussing effective use as a function of time, we link to the prior call for assessing representation theory – which EUT draws upon – in chaotic environments (Burton-Jones et al., 2017). In particular, we discuss the meaning of pursuing representational fidelity in-use under time pressure by discussing timeliness concerning three levels of use: (1) transparent interaction; (2) representational fidelity; (3) situational awareness. This study advances the theoretical understanding of the construct of effective use by assessing it empirically. The scale we develop supports the tri-dimensional and time-dependent nature of effective use in chaotic environments as posited in previous literature on EUT in emergency management (Bonaretti & Piccoli, 2018b).

4.2 A Socio-Political Perspective on EAS' implementation

This section presents a diachronic perspective on EAS' adoption and implementation. The goal is to understand how the strategic purpose of the EAS has developed into its current shape. Identifying the strategic *purpose* is critical to understand what system's users intend for "effective use" of the system (Burton-Jones & Grange, 2013). In backtracking the evolution of an EAS's strategic purpose, it is critical to contextualize our theoretical lenses to the not-for-profit sector. Specifically, prior literature suggests that government organizations' strategies do not respond to the same criteria of for-profit organizations (Silva & Hirschheim, 2007). When competing on a market environment, organizations (i.e., companies) seek to "rapidly innovate, adapt, and reconfigure themselves to match the changing environment." (O. A. El Sawy & Pavlou, 2008, p. 139) Pub-

[2]By "grey literature" we mean manuscripts produced by government organizations outside the traditional academic publication process (e.g., annual reports, manuals)

lic emergency management organizations (e.g., FEMA), instead, aim for stable solutions that are malleable enough to address emergent needs. They do not seek continuous innovation to increase their competitive advantage. There are, instead, incentives for innovation to occur in response to socio-political stressors (Avgerou, 2000). Among all, one factor that may influence the strategic choices is the public opinion and its interpretation of government actions (Silva & Hirschheim, 2007). Regulations and laws for implementing EAS are not uniquely based on the technical or substantial merit (B. S. Fisher, Hartman, Cullen, & Turner, 2002). Instead, they intermingle technical and socio-political considerations. In particular, the following sections draw on a Punctuated Equilibrium perspective to offer a diachronic perspective on the the evolution of campus EAS.

4.2.1 A Punctuated Equilibrium Perspective

The theory of Punctuated Equilibrium posits that socio-political events are the main drivers for change and innovation of a system's strategic objectives (Gersick, 1991). In particular, scholars adopted the theory to study IS strategies in public organizations (Silva & Hirschheim, 2007). The need to adopt a *ad hoc* perspective for a public organization arises because:

"government organizations [...] are characterized by strong bureaucratic structures and limited resources that almost by definition eschew notions such as agility and dynamic capabilities. Even the proponents of agility and dynamic capabilities recognize that their theoretical boundary refers to private organizations immersed in rapid and dynamic competitive environments, which is not the case for government organizations." (Silva & Hirschheim, 2007, p. 328)

From that presupposition, it follows that organizations remain static for long periods until they are "punctuated" by a revolutionary event (Gersick, 1991). In turn, revolutionary events may change an organization's IS strategy. While strategies typically evolve incrementally, revolutionary events rapidly prompt strategic changes by transforming the organization's socio-political structure (Silva & Hirschheim, 2007, p. 333). The socio-political structure consists of: (1) core beliefs and values; (2) services, technologies and political time; (3) the distribution of power; (4) organizational arrangements; (5) control systems (Silva & Hirschheim, 2007, p. 331). Revolutionary periods may produce radical shifts in how organizations interpret the effective use of an informa-

tion system. The nature of those events can be internal or environmental. An example of *internal* socio-political revolution is a change in policy or regulations (Silva & Hirschheim, 2007). Instead, *environmental* revolutions happens because of exogenous drivers. To understand how the concept of EAS' effective use has been evolving, we scrutinized two events that produced major shifts: the 1990 Clery Act (internal event), and the 2007 Virginia Tech (external event) (Figure 4.1). Both those events reshaped the socio-political structure of organizational core beliefs about the role of emergency communication.

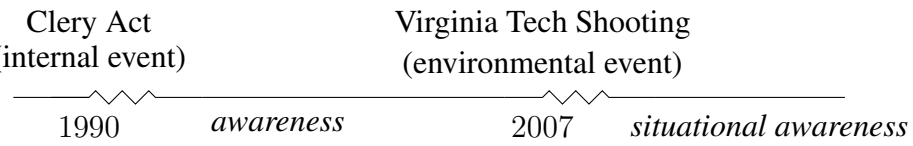

Figure 4.1: Timeline of socio-political events impacting strategic use of EAS

4.2.2 The 1990 Clery Act and the Strive for Awareness

The 1990 Clery Act (20 U.S.C. 1092(f)) mandates all public universities to report annually on on-campus security policy and crime statistics. The core belief is that increasing the awareness about criminal activities and prevention initiatives will increase individuals' ability to respond to security threats. The act is named after Jean Clery, a 19-year-old student who was murdered and raped on Leigh University's campus in 1986. When her family started their campaign for safer campuses – which lead to the emanation of the Act – one motivation was that, had she knew about the skyrocketing crime rate on her campus, she could have taken better countermeasures to protect herself. Perhaps even enrolling in a different university. A pillar of the Clery Act is to articulate what actions to take to increase *awareness*. For instance, the act mandate Operation Emergency Offices to implement information systems for collecting and distributing crime information to the campus community. Initially, the dissemination of relevant information happened via hard-copies of the Clery Report. Later on, technology developments enabled to distribute digital copies via email. Today, every university's website has a URL link to the annual Clery Report.

The increasing pervasiveness and ubiquity of information technology (IT) (Yoo, 2012) provided new channels for disseminating safety information. That enabled emergency offices to im-

plement systems for redundant and multi-channel (e.g., email, SMS) communication to increase the pervasiveness of emergency communication. The popularization of mobile devices enabled the communication of ongoing threats, awareness to become *situational*. In 2006, Virginia Tech started to study available options for EAS (Tech, 2007). However, the strategic importance of implementing EAS for timely dissemination achieved national resonance after the 2007 Virginia Tech Shooting.

4.2.3 The 2007 Virginia Tech Shooting and the Strive for Timely Communication

The 2007 Virginia Tech Shooting made uttermost clear that *timeliness* of emergency communication is critical to claim the successful implementation of Emergency Alert Systems (EAS). On April 16, 2007, at about 7:15 am, two students were shot on campus. Despite immediate evidence that the shooter was at large and representing an ongoing threat, the students received an email warning only at 9:26 am, almost 2 hours after the shooting. Meanwhile, shortly after 9:00 am, the shooter walked back Norris Hall (0.5 miles from the first shooting) and killed 32 people, wounding 17. In 2014, Virginia Tech paid $32,500 in Clery Act Penalties over failing to issue a timely warning after the first shooting. University's representatives claimed that standards that defined *timeliness* "did not exist at the time"; in fact, a strict definition of what constitutes a timely warning does not exist to this day (FEMA, 2017).

4.2.4 Current socio-political structure: regulation on Emergency Communication

The previous sections presented two socio-political events that contributed to redefining the requirements of a system for emergency communication. While the system focused initially on raising awareness, the 2007 Virginia Tech Shooting showed the importance of such awareness to be situated in time in case of an emergency. The current implementation of the EAS reflects the dual role of emergency communication. The current US regulation for campus emergency notification prescribes two types of emergency communication: *emergency notification* for immediate threats, and *timely warnings*. Emergency notifications are issued in case of a terrorist incident, armed suspect, earthquake, approaching forest fire, etc. and must include information for "both response and evacuation" (FEMA, 2017, p. 6-5). The goal is to raise *situational awareness*: "the

perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future." (Endsley, 1995, p. 36). Timely warnings, instead, are for threats that are not ongoing or time-sensitive, such as past criminal activities. Their goal is also to "enable people to protect themselves" (FEMA, 2017, p. 6-12). For instance, authorities may disseminate a timely warning – where "timely" means within 48 hours (University, 2018) – to raise awareness regarding multiple break-ins affecting a certain area, which in turn should increase vigilance.

In compliance with the Clery Act's founding principles, each year end, universities must report the statistics regarding safety and crime issues on campus. Federal Guidelines stress the importance of *timeliness* and *accuracy* of warning messages (FEMA, 2017), implicitly conceptualizing EAS' performance independently from recipients' interaction with the system. Figures to be reported include EAS' performance measures, such as the rate of pervasiveness, and how quickly the system dispatches the alert messages. When it comes to the SMS alert module, pervasiveness is measured as the number of the SMS successfully delivered to the total number of subscribers. The time for completing an SMS mass dissemination is the second measure of performance.

In other words, performance is measured based on qualities of the EAS *before use* (e.g., timeliness, the pervasiveness of an alert's mass-sending) (Burton-Jones & Grange, 2013). A key tenant of studying the system-in-use is that information quality measures are *not* apt indicators of the system's performance. They offer limited insight about how the system performs once deployed. Thus, measuring the artifact before use may constitute a misleading measure of effective use (Burton-Jones & Grange, 2013). Scholars should reorient their focus on the understanding of the *system-in-use*, and the assessment of system's *effective use* (Burton-Jones & Grange, 2013).

4.3 The EAS in the US

To contextualize the notion of effective use to an EAS, this section presents the system implemented at a large US state university that we call, hereafter, "University". Figure 4.2 represents an archetypal EAS that is representative of systems adopted by US universities for emergency communication. The EAS enables multi-channel crisis communication by dispatching alerts through

email, text, social media, desktop alerts (for computers on the campus network), university web-page. Multi-channel distribution of emergency information increases the chances of timely alerting possible victims. This principle of redundancy of the distribution channels inherits the spirit of the Clery Act and to pursue awareness.

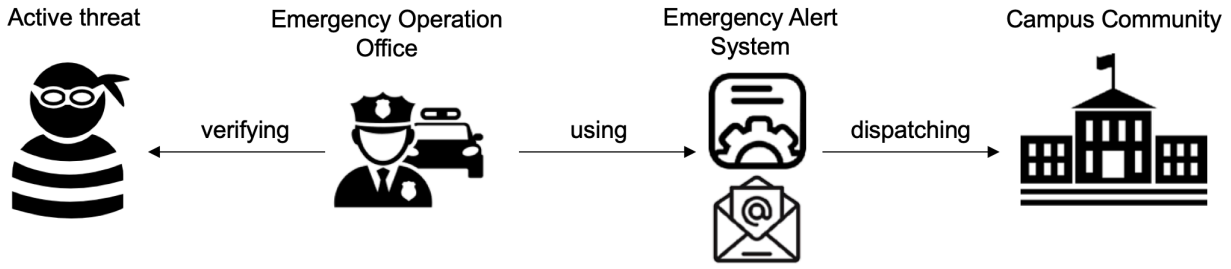

Figure 4.2: Information flow in an archetypal EAS system

However, while EAS enables multi-channel communication, this study focuses on SMS alerts. A survey of University's student population reveals that SMS and email are the preferred media for receiving emergency communications (see Table B.1). Thus we pragmatically focus our empirical work on SMS. The module for mobile text messaging enables mass-sending of an emergency SMS (e.g., Figure 4.3) to the subscribers within the campus community. The subscription is voluntary, and students receive a reminder to opt-in at the beginning of every semester. Other institutions in the US instead require students to opt-out, which may increase subscriptions. As part of this research, we interviewed the University's emergency operation officer, who claimed that University traditionally adopts an opt-in strategy because some carriers in the US charge for incoming SMS. Based on a University's student sample, we estimate that 82% (n=393) of the students are currently registered to receive SMS alerts. From self-reported information regarding the EAS performance at University, there are multiple reasons for failures in SMS communication besides absence from the distribution list. From a test conducted in early 2019 (University, 2019), the overall failure rate of the SMS alert communication reaches 9-10%. The breakdown for failures is: (1) SMS may fail to be accepted by the carrier (3% in our system) and thus are never delivered; (2) mobile devices may fail to timely process the SMS (3%); (3) the subscriber is unable to receive an SMS because his phone is turned off, there is low/no signal, the number provided is incorrect (3-4%).

Additionally, the delivery rate of SMS is limited (about 100 per minute on University's campus), and may slow down if the message exceeds the max limit of 140 characters/SMS. Therefore, it is paramount to keep an updated list of recipients (e.g., regularly delete alumni) and to be parsimonious in sending SMS alerts to avoid overwhelming cellular networks. For communications that are not time-sensitive – e.g., follow-up messages such as "the suspect has been arrested" – the university will use emails, news feeds, or social media only. Using SMS alerts parsimoniously is also intended to increase the salience of alerts, and to avoid unnecessary costs for mass-sending. In total, University sent 5 SMS in 2017, and 9 in 2018.

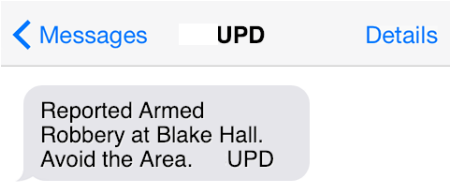

Figure 4.3: An time-dependent conceptualization of the EUT model contextualized to EAS

4.4 Theoretical Background

After presenting the socio-political background, the next section presents the theoretical lenses we use to study the effective use of EAS: *Effective Use Theory* (EUT) (Burton-Jones & Grange, 2013). Table 4.1 defines and summarizes the relevant concepts at play, while Figure 4.4 illustrates the proposed contextualization of the EUT model to EAS (Bonaretti & Piccoli, 2018b). Adopting EUT means to embrace two principles of studying system's use: (1) to focus on the system *in-use*' (2) to distinguish between system's *effective use* and its impact on *performance* (Burton-Jones & Grange, 2013). Focusing on the system *in-use* means to study IS artifacts enacted in their social context (Burton-Jones & Grange, 2013, p. 639). Conversely, studying the system *before-use* means to focus on the system's qualities independently than their use and social context. For instance, for an EAS, the speed of dispatching SMS alerts is largely a technical property of the system before use. How timely users access the SMS alert is, instead, an attribute of the system in-use.

Second, EUT distinguishes between *effective use* and the impact of system's use on *perfor-*

mance (Burton-Jones & Grange, 2013). Prior literature contextualized the concept of effective use in emergency environments as follows: the seamless interaction with a systems to retrieve digital representations that increase situational awareness about a relevant real-world domain (Bonaretti & Piccoli, 2018b) (Figure 4.4). Performance, instead, is a function of the attainment of organizational goals (Burton-Jones & Grange, 2013). Such goals depend on the socio-political organizational structure and contingencies. They do not obey to a system-in-use perspective. For instance, the policy change introduced by the 1990 Clery Act called for implementing an information system[3] that focused on information quality measures (e.g., variables to include in a report about, frequency, and distribution channels). Through the EUT lenses, we reconsider the University's understanding of what constitutes EAS' effective use in light of IS research on EAS. Drawing on prior research, we select as a measure of the EAS' performance the recipient's "willingness to comply" upon receiving, via an alert message, the guidelines for protecting herself (Han et al., 2015). We ground the selection of the performance measure in previous literature rather inferring it from the current organizational socio-political structure.

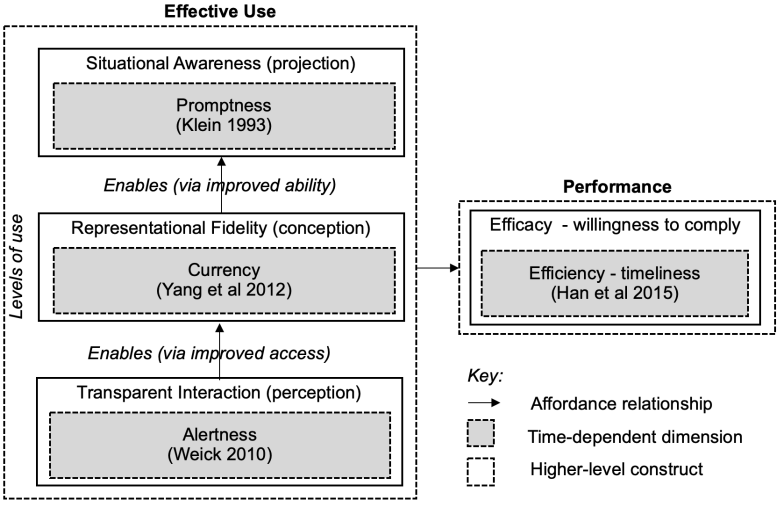

Figure 4.4: A sample emergency message

In the following sections, we present the concept of effective use from a EUT perspective, and contextualize it to define what it means to use an EAS effectively from a native IS perspective

[3]Here the term "information system" is used with the broad connotation of "system of signs" (Watson, 2014), thus including the ensemble of processes and users involved in producing static reports and Clery Act deliverable

Table 4.1: Relevant constructs for our theory development

Constructs from EUT (Burton-Jones & Grange, 2013)	
Transparent Interaction	The user's ability to seamlessly engage with the system
Representational Fidelity	The extent to which a user retrieves representations that faithfully represent the real-world domain
Informed Action	The extent to which users act upon digital representations to improve their state
Construct from an EMIS contextualization of EUT (Bonaretti & Piccoli, 2018b)	
Situational Awareness	The ideal status of intelligibility of digital representations of an event within a span of time and space enabling the assessment of the projected effectiveness of actions on the environment of interest in the near future
Constructs from Emergency Alert Systems (Han, Ada, Sharman, & Rao, 2015)	
Compliance	The extent to which the recipient follows the guidelines from the alert message

– that of EUT (Burton-Jones & Grange, 2013). Rather than focusing on an EAS' qualities, we study system use from an SMS alert's recipient perspective. EUT suggests that higher situational awareness about a verified threat will increase performance (willingness to comply) (Bonaretti & Piccoli, 2018b). We enrich the conceptualization of effective use by including a discussion of how time-constraints impact effective use, and surface, using a system-in-use perspective, impediments for effective use beyond information those quality dimensions, i.e., timeliness and accuracy.

4.4.1 Effective Use Theory

EUT builds on a Representation Theory (RT) perspective of information systems to develop a notion of effective use (Burton-Jones & Grange, 2013). Drawing on RT means to see an information system as a "semantic system" (Burton-Jones et al., 2017) that users interact with to retrieve faithful digital representations of the real-world; representations then inform users' acting in their environment. From the RT perspective, an information system is similar to a natural language: systems of signs that humans use to represent and communicate the reality. Similar to linguists, who focus on pragmatics to understand a language *in use*, the IS scholars should study any information

systems *in use* (Burton-Jones & Grange, 2013).

While research in RT continues to develop independently of EUT, the two theories mutually influence each other, which suggests that the implications of assessing (i.e., corroborating or falsifying) RT propagate to EUT. For instance, EUT embraces RT's principle that an information system is a semantic system, not simply a system of data-tokens (i.e., "signs' systems"). Thus, scholars should focus on how users "comprehend" the system, acknowledging that differences in how users retrieve and comprehend digital representations of the real world can be meaningfully studied only in-use.

The principal tenant of EUT is to study effective use in terms of "both pragmatics and semantics" (Burton-Jones & Grange, 2013, p. 638) to overcome the limitations of assessing the usefulness of a system *before use*. However, our socio-political analysis suggested that – in implementing EAS – public organizations moved from a "semantic" signaling power perspective: demonstrating to the public opinion the commitment to increase awareness through disclosing crime statistics. This interpretation of public organizations' implementations strategies and public opinion is consistent with prior research, which posits public organizations seek to signal compliance with core organizational values (Silva & Hirschheim, 2007). Signaling innovation (e.g., the 1990 Clery Act) may facilitate emotional recovery in the aftermath of a disaster or tragic event. However, from an IS perspective, studying the effective implementation and use of a system means to focus on how the system performs *in-use* concerning three levels of use: (1) transparent interaction; (2) representational fidelity; (3) situational awareness (Bonaretti & Piccoli, 2018b). While EUT originally focused on informed action (instead of situational awareness), the interest for an ostensive measure of use focusing on *projections* of actions (i.e., situational awareness) has been proposed both in RT research in chaotic environments such as emergencies (Bonaretti & Piccoli, 2018b), and in non-chaotic ones (Bremhorst, 2018).

According to EUT, to achieve effective use users should first experience *transparent interaction*, by "accessing the systems representations unimpeded by its surface" (Burton-Jones & Grange, 2013, p. 643). That means transparent interaction ensures that users interact with the

surface structure to access the system's *deep structure*. The *physical structure* enables the interaction between surface and deep structure. Through the surface structure, users do not retrieve raw data tokens, but rather *digital representations* of the real-world domain. Ideally, digital representations will faithfully mirror the real-world, enabling *representational fidelity* – the second level of effective use. Since the system is a semantic one, fidelity is not an intrinsic quality of the representations, but it depends on users' ability to comprehend those representations. Finally, fidelity is more likely to increase situational awareness – the third level of effective use. Therefore, faithful representations are the ground for informed decision-making. The three levels of use are part of a "hierarchical affordance network", meaning that each lower-level affordance is necessary to activate an higher-level one (Figure 4.4).

The next sections provide literature-based definitions of the levels of use contextualized to the context of this research. In particular, we develop the idea of defining time-dependent levels of use. For transparent interaction that means to account for *alertness*, the affordance "to notice that something that is out of place, unusual, or unexpected" (Weick, 2010, p. 345). For representational fidelity that means to account for *currency*, the extent to which the representation is up-to-date. For situational awareness that means to account for *promptness*: the rapidity of leveraging representations for fast decision making (Klein, 1993).

Transparent interaction

Transparent interaction is a user's ability to seamlessly engage with the system, which means to access its deep structure through its physical structure. Prior research started studying transparent interaction by juxtaposing the concept with *ease-of-use* (Burton-Jones & Grange, 2013). This approach may be misleading unless we surface the impediments of transparent interaction when using EAS and, in particular, SMS alerts. The pervasiveness and familiarity of the US population with SMS and mobile devices suggests that accessing an SMS is easy. The interaction with an SMS alert system will typically be seamless. However, this assumption reflects a *system-before-use* perspective of transparent interaction. It focuses on a *ex ante* ability to access SMS on a mobile device independently that SMS use in EAS. Of course, low ease-of-use due to interface-related issues

will hinder timely interaction, but there are even more ground-level impediments of transparent interaction in the EAS context, such as usage habits. People show different levels of vigilance towards incoming SMS notifications that make the interaction less timely and "transparent". We call the ability to timely notice an SMS notification *alertness* (Weick, 2010, p. 345). This adds time-dependency to the affordance of transparent interaction. Interaction is "transparent" only if it actualizes in a useful time. By that, we mean quickly enough to enable users to act upon a digital representation of an active threat and take countermeasures to protect themselves (e.g., to avoid the area).

Representational fidelity

Representational fidelity[4] is the extent to which a "user is obtaining representations from the system that faithfully reflect the domain being represented." (Burton-Jones & Grange, 2013, p. 643) Prior literature conceptualizes fidelity as the extent to which a representations captures "the truth, the whole truth, and nothing but the truth" (Burton-Jones & Volkoff, 2017), otherwise *accuracy* and *completeness* in information quality jargon (Nelson, Todd, & Wixom, 2005, p. 204). In a fast evolving environment, representational fidelity is a function of the extent to which representations are up-to-date (Burton-Jones et al., 2017). Consistently with prior literature, we call *currency* the system's ability to reflect the present state of the real world (Xu, Benbasat, & Cenfetelli, 2013). Thus, fidelity includes the extent to which an EAS' user retrieves current representations of an active threat. We stress that the EUT perspective orients the assessment of currency from a pragmatic standpoint concerning the system in-use. Timeliness or accuracy before-use have little intrinsic value. In fact, it is unclear whether maximizing accuracy and timeliness of alert messages is always the best strategy.

Different approaches are available to handle ambiguity, uncertainty, or untimeliness of emergency-related information. This observation surfaced from interviewing the University's emergency officer. He was hesitant regarding the intrinsic value of maximizing representational fidelity of an

[4]Prior literature used both "fidelity" and "faithfulness" to define accurate and complete representations (Burton-Jones & Grange, 2013). Instead, we stick to "fidelity" only.

ongoing threat: "You are behind the event. Always. Unless it is a case like Ohio state, where the suspect did not realize there were a police officer 150 ft. behind him." Providing a digital (geospatial) representation of a threat should account for how users will make sense of the digital representation (Burton-Jones & Grange, 2013). He commented that another option is to obliterate geospatial information from emergency messages, for instance, in the presence of an active shooter. In those cases "the best practice is to lock everything down and walk back from that", having people to wait for the "all clear" rather than trying to leave the scene. However, the skepticism for communicating incomplete or outdated information contrasts with EUT's teleological underpinnings that "people take actions to create and use information systems so that they can obtain better representations than available elsewhere, such as manual system" (Burton-Jones & Grange, 2013, p. 640).

Situational Awareness

Situational awareness is "an ideal status of intelligibility of digital representations of an event within a volume of time and space enabling the assessment of the projected effectiveness of actions on the environment of interest in the near future." (Endsley, 1995, p. 36). From the EUT perspective, situational awareness represents the ability to project actions upon digital representations of the surroundings. Researches combined situational awareness with representation theory to describe how the decision-making process unfolds (Bremhorst, 2018), and to generalize EUT to the emergency management context (Bonaretti & Piccoli, 2018b). Conceptualizing effective use as projected action, instead of the action itself, has a major epistemological implication: choosing between a *performative* (Orlikowski, 2007, p. 815) or *ostensive* (Latour, 1984, p. 272) the perspective of effective use. Previous literature in EUT seems to bind the level of effective use on a "doing" (informed action). However, prior research advocated for an *ostensive* perspective as apter to measure of EAS' effective use in chaotic environments such as emergencies (Bonaretti & Piccoli, 2018b). One reason is that individual action during emergencies may be impeded by environmental elements such as physical obstacles, external agents, and the like, leading to poor execution. A potential action may suffer actualization issues that are independent than the system's

effective use. For example, an individual who receives an emergency SMS is unable to comply and promptly leave the area because of disability. Nonetheless, the EAS enables the *projection* of a would-be informed action. Therefore, we consider *situational awareness* as a dimension of the effective use of an EAS.

Performance

EUT defines performance as the extent to which the system supports the achievement of organizational goals (Burton-Jones & Grange, 2013). *Performance* (or *effectiveness*, not to be confused with *effective use* is a bi-dimensional construct consisting of *efficacy* and *efficiency*. Efficacy describes the extent of goal attainment. Efficiency, instead, measures the level of attainment relatively to the level of input. There are two reasons to distinguish between these two dimensions. First, to avoid circular reasoning about system effectiveness as in statements like the following: "Effective use is one that produces situational awareness. If a user achieves situational awareness, then system use was effective". Second, measuring both efficacy and efficiency is key for learning from unsuccessful implementations, for example from efficacious but inefficient implementations.

In the review of the socio-political structure, we showed that national guidelines measure EAS's performance on its ability to dispatch emergency messages (FEMA, 2017) timely. However, from a EUT perspective, timeliness is rather a quality of the system before-use. To conceptualize performance according to EUT, we draw on IS scholarship. Prior research on EAS proposed *compliance* as a measure of performance (D. Fisher et al., 2019; Han et al., 2015; Lee, Chung, & Kim, 2013). Therefore, EAS use is efficacious when recipients comply with the content of the alert message (e.g., "avoid the area"), and is efficient if users do so without hesitating (i.e., to verify information). This definition of performance enables to discriminate between organizational goal attainment and the effective use of the EAS. The organizational goal is that students take actions to protect themselves. Effective use, instead, is to enable the *projection* of countermeasures to protect themselves. To conclude, a definition of performance is paramount to discriminate between the purpose (or *intended use*) of the EAS and the outcome that we expect the system to prompt when used as intended.

4.5 Hypothesis Development

Our theoretical development showed that the intended use of an EAS is to increase situational awareness to improve compliance with personal safety guidelines. From a socio-political perspective, emergency response builds on a fundamental working assumption: increasing situational awareness about would-be threats helps individuals take countermeasures for protecting themselves. We define the intended use of an EAS to increase situational awareness; *effective use* is the extent to which individual situational awareness increases when interacting with the system. Moreover, we defined the performance of an EAS the extent to which it prompts users' compliance. Therefore, we posit that:

H1. Effective use has a positive effect on performance

4.6 Method

4.6.1 Experimental Setting

We test the measurement model we propose in Figure 4.4 with a survey administered in a behavioral computer laboratory over a month in February 2019. Participants take the experiment sitting in a cubical that hinders interaction with other participants. Attendees (n = 393) were undergrad students who voluntarily attended the experiment for school credits. The average age in our sample was 21.5 (SD= 2.9) and the proportion of males (M = 193, SD = 6.95) was not significantly different than 50% (z = -1.4, $p > .05$). Since the student come from the local College of Business, they are both familiar with the system and the campus geography.

We distribute the survey using an online system (Qualtrics). A list of the question items is included (Table 4.2). A survey is an apt method, in line with prior literature (Han et al., 2015; D. Fisher et al., 2019), because students are indeed the users of the system being investigated. At the beginning of the survey, students are informed that the information they provide will help to improve the effectiveness of the current emergency communication system. Participants respond to the question after seeing a screen-shot (Figure 4.3) of an actual emergency SMS.

Table 4.2: Text messages used in the survey

	n	SMS content
SMS 1	n=67	Reported armed robbery north side of Kirby Smith Hall. Please avoid the area
SMS 2	n=71	Reported Armed Robbery at Cypress Dr and W. Chimes St. Use caution in the area.
SMS 3	n=61	Reported armed robbery at Nicholson Dr. & West Chimes St. LSU Police on scene. Limited suspect info, reported on foot with gun in unknown direction.
SMS 4	n=68	Reported armed robbery, Res College, North. Police are on the scene, use caution in the area
SMS 5	n=55	Reported Armed Robbery at Blake Hall. Avoid the area.
SMS 6	n=71	Reported armed robbery on campus. Avoid dark areas.

4.6.2 Instrument development

To design the survey we adapted existing indicators from (Han et al., 2015) which showed consistent loading, in particular from actionability, criticality, and safety threat, and we recombined them to measure *situational awareness*. The development of the indicators for transparent interaction is instead theory-driven from question items suggested in (Burton-Jones & Grange, 2013). Our theoretical development showed the importance of considering the impact of time constraints on the levels of use (Figure 4.4). We included question items to measure alertness, currency, and promptness as *dimensions* of the levels of use. Our approach treats timeliness as a dimension of the levels of use, rather than as a construct in its own. For instance, we do not treat timeliness as a moderator. Instead, we advocate for time-dependent measures of the levels of use. This approach draws on prior research, which noted how the construct of timeliness tend to cross-load with different dimensions of use (McKinney, Yoon, & Zahedi, 2002, p. 302).

To validate the set of indicators in the measurement model, we organized a focus group with four undergrad students to run a pilot and improve the clarity of the question items. First, we asked the students to fill the survey and to note down on a paper copy of the survey the question items that they found unclear, hard to project themselves into. Then we informed them about the model we aim to test and opened for discussion. The main suggestion was to ask the responders

to imagine themselves to be on campus while they receive the alert. We did so following a recommendation of two members of the focus group who suggested that failing to ask participants to imagine themselves on campus while they receive the SMS may decrease the salience of alert message.

4.6.3 Confirmatory Factor Analysis

To assess the validity of the model of effective use presented in Figure 4.4, we use a Confirmatory Factor Analysis (CFA). Figure 4.5 represents the fitted model, which relies on reflective indicators to measure the three dimensions of effective use. Using reflective indicators means that the constructs representing the three levels of use are not directly observable. Instead, using reflective measures assumes that they can be observed indirectly as reflected in the exogenous indicators (depicted as squares in Figure 4.5. This assumes that while the selected items should reasonably tap to each level of use, the model does not assume the list of those items to be comprehensive. For assessing effective use as a multi-dimensional second-order construct, the CFA considers transparent interaction, representational fidelity, and situational awareness as first-order factors. Effective use, the second-order factor, is measured using those three levels of use as its reflective indicators. The model in Figure 4.5 shows that transparent interaction, representational fidelity, and situational awareness altogether measure a higher level concept (Richard P. Bagozzi & Heatherton, 1994). We use the factor scores calculated using CFA to measure *effective use* and to predict *performance* measured using item *perf1* from Table 4.2. Performance is predicted using simple linear regression:

$$y_i = \beta_0 + \beta_1 EffectiveUse$$

4.7 Results

CFA is appropriate when testing relational hypotheses within a models constructs. We handled missing data using listwise deletion. Although we also considered missing data imputation methods, we opted for listwise deletion because we considered missing answers a symptom of partic-

ipants' lack of focus while completing the survey. We rescaled and reverse-coded item t3, which is the only covariate that is originally not collected as a 1-to-7 Likert-scale (it is expressed in minutes). Rescaling was necessary to ensure comparability of indicators' loadings. Mardias (1985) test rejects the hypothesis of multivariate normality ($p < .01$), but there is no evidence of a strong violation of normality since all skew indexes were below 3.0 and kurtosis indexes below 8.0. The analysis of the covariance matrix did not reveal major differences, with the ratio of the largest to the smallest variance below 10.0. We fitted the model using the R Lavaan Package v.0.6.3 (Rosseel, 2012) and ML to estimate the unbiased Wishart variance-covariance matrix Figure 4.5. Wishart method will give estimates that are closer to those of other programs like EQS, LISREL or AMOS. We did so in the spirit of facilitating cross-comparison of the results in this research area. The factor loading of one indicator for each latent variable is set equal to 1.

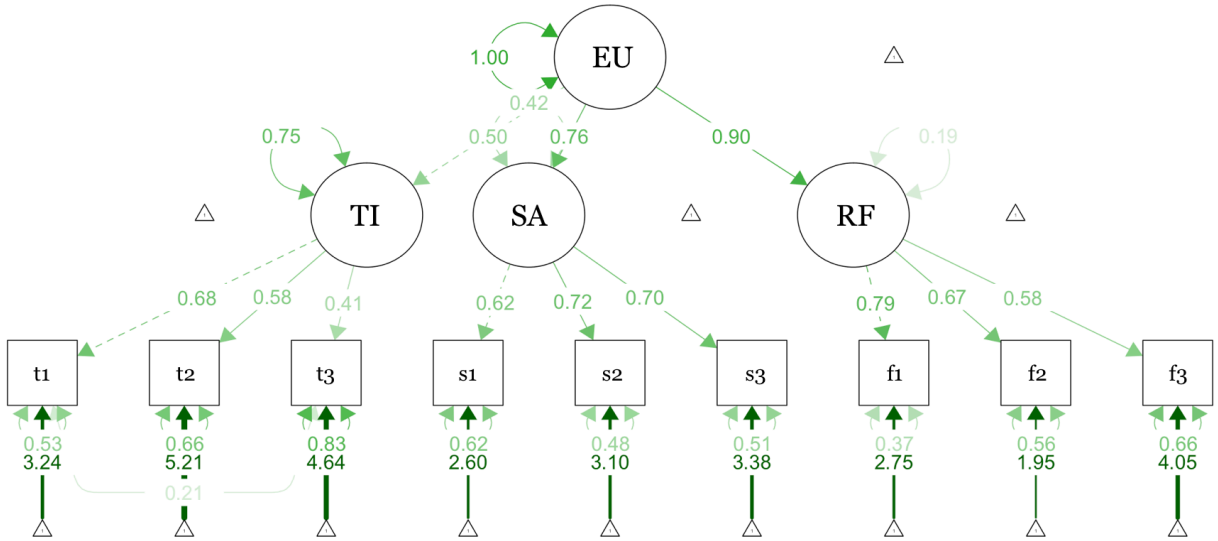

Figure 4.5: Measurement model

We modeled Effective Use as a second-order construct to reflect the original formulation (Burton-Jones & Grange, 2013). Effective Use consists of Transparent Interaction, Representational Fidelity, and Informed Action. This measurement model is supported, fitting significantly better than the base model without a second-order factor $\chi^2(3, N = 23)=42.6$, $p < .01$. The error terms are uncorrelated but for *t1* and *t3*. Since both indicators measure a time-dependent dimension of transparent interaction, there there is theoretical support to allow correlation between the error terms.

While the hypothesis of perfect fit is not supported ($\chi^2(23)=44.78$, $p < .01$), the model RMSEA = 0.049, p=0.495, 95% CI [0.027, 0.070], indicates "very good" fit, and the upper bound of the confidence interval is below the threshold for "good fit" (RMSEA $< .08$) (Browne & Cudeck, 1993). Other commonly reported measures of good fit also support our specification (GFI=0.998, AGFI=0.995, GFI=0.998, NFI=0.946, NNFI=0.957, CFI=0.972, SRMR=0.036). Thus, we consider the model fit satisfactory while acknowledging that a different specification may lead to a better model fit.

The linear regression of *effective use* to predict *performance* shows a significant positive effect of effective use on the dependent variable, b=0.432, t(388) = 9.058, p $< .001$. Effective use also explained a significant proportion of variance in willingness to comply, R^2 =0.222, F(1, 388) = 82.047, p $< .001$.

Table 4.3: List of the survey question items

Performance	
perf1	When I receive an emergency notification message, I would comply with the alert message (7-point Likert scale)
Situational Awareness	
s1	If I follow the instructions in the message, I will be protected (7-point Likert scale)
s2	The direction in the message will help me plan my next step (7-point Likert scale)
s3	I can act timely on the information that I received in the message (7-point Likert scale)
Representational Fidelity	
f1	The threat will be active upon receiving the message (7-point Likert scale)
f2	The message will convey the urgency for taking action (7-point Likert scale)
f3	The message will be sent only when necessary (7-point Likert scale)
Transparent Interaction	
t1	When I receive any SMS, I read it right away. (7-point Likert scale)
t2	I am always reachable via SMS when I am on campus (I carry my phone, iWatch, or similar devices) (7-point Likert scale)
t3	On average, how long does it take you to read an SMS that you received? - Please type in an amount in minutes (numeric)

4.8 Discussion

In this study, we set out to assess the conceptualization of effective use as a tri-dimensional construct spanning transparent interaction, representational fidelity and informed action (Burton-Jones & Grange, 2013) - which we reformulate as situational awareness. Because of our focus on emergency management systems, we characterize each level of use as time-dependent (Bonaretti & Piccoli, 2018b). Based on this recontextualization of Effective Use Theory (EUT) we advance a measurement model that treats effective use as a higher-level construct consisting of: (1) transparent interaction; (2) representational fidelity; (3) situational awareness. While, overall, the analysis supports effective use as a tri-dimensional construct, its conceptualization as a hierarchical affordance network is supported only in part. According to this conceptualization, each lower level of use enables a higher level one, which suggests that factor loadings for levels of use that are "higher" in the hierarchy should be higher. Instead, $\lambda_{SA} = .76$ is less than $\lambda_{RF} = .9$, which suggests that, on this instrument, effective use loads more on representational fidelity than situational awareness. This result possibly reflects that representational fidelity is not actualized strongly enough to enable situational awareness.

Our theory testing contribution consists in evaluating the link between effective use, measured as a second-order construct, and organizational performance, measured as users willingness to comply with directives from the emergency alert system (EAS). The hypothesized link is supported. This result provides preliminary support for the extension of EUT to chaotic environment, thus responding to the recent calls by EUT theorists (Bonaretti & Piccoli, 2018b). In aggregate, our results show that the development of a measurement instrument makes a twofold contribution. First, it helps adopt EUT as a Type-V theory to guide EAS design (Gregor, 2006) - a contribution to the practice of EAS design currently dominated by principles rooted in grey literature rather than rigorous IS design principles grounded in native IS theories such as EUT.

Second, it articulates theory-driven design objectives into dimensions of the constructs that it measures. Specifically, it provides question items to inform the actualization of each level of use. This is also important because it responds to a prior call for developing measures of effective use, in

particular, to assess transparent interaction, for which no scales currently exist, and ease-of-use is considered the closest measure thereof (Table A.1 in (Burton-Jones & Grange, 2013)). However, ease-of-use is typically studied in simple contexts, where vigilance and commitment to using the system can be legitimately assumed. For instance, ease-of-use for an analyst using a decision support system is measured on a non-volitive use of the system, since the organization dictates the use of the systems.

In EAS in-use, instead, interaction is prompted *by* the system, and the use is volitive. This distinction implies that the construct of transparent interaction in the context of EAS cannot assume interaction is ongoing and then merely focus on ease-of-use. Instead, it is critical to account for whether and how timely transparent interaction actualizes. Therefore, assessing ease-of-use of an EAS independently of any time constraints is largely a measure of transparent interaction *before-use*, since it does not consider the time-pressure in the presence of an ongoing threat. When scrutinizing items from prior research, scholars should consider whether measures of ease-of-use, accessibility, or usability, capture the essence of transparent interaction relative to the context of use.

The conceptualization of the levels of use as time-dependent constructs for practitioners as well, who have mostly intended timeliness as how quickly alerts are distributed. Instead, the measurement instrument draws the attention on the recipient's ability to timely access a digital representation of a threat (alertness), the ability to retrieve up-to-date representations (currency) and to quickly project how to act upon them (promptness). Finally, adhering to the EUT perspective also has two teleological implications which impact EAS design decisions, and the definition of intended use: (1) the system design should leverage the users' ability to extract meaning from the system; (2) situational awareness is the ultimate goal of the system's effective use. A EUT perspective would differ from approaches that seek to manipulate users' actions by leveraging extrinsic motivations (e.g., subjective norms), or by persuading users leveraging the quality of the system before-use, such as its level of trustfulness.

4.9 Limitations and Future research

The major limitation of assessing EUT with a lab experiment is methodological since we did not see a way to capture a *performative* measure of compliance. While EUT posits a positive relationship between effective use and performance, the lab environment allows the measurement of performance only in terms of *willingness* to comply, rather than actual compliance. Future research should seek to proxy-measure the discrepancy between *willingness* to comply and *compliance*. We asked the participants to pin on an interactive map the location of the threat communicated in the SMS, which comes formatted as a building/street name (Figure 4.3). This measure is important to evaluate a user's ability to comply with directives such as "avoid the area", which can be intentionally actualized only when the user is able to identify the location in the real-world environment.

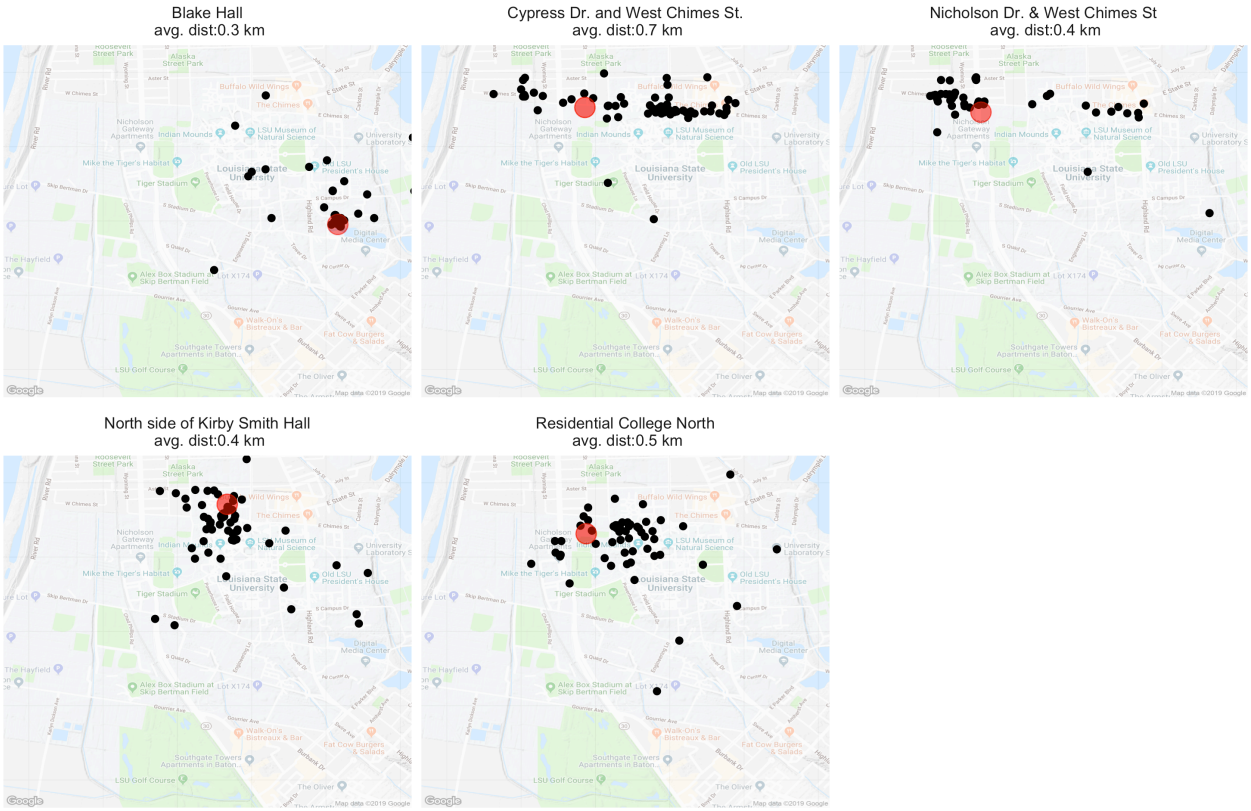

Figure 4.6: Spatial awareness of recipients (black) versus actual location (red)

Figure 4.6 shows the locations that participants pinned on the map when asked to locate the threat (black dots), versus the actual location of the threat (the red dot). For instance, for those

treated with SMS 3 (Table 4.2), the average estimated distance from the actual location is about 700m - a significant discrepancy. Assuming the ability to locate the robbery on the map is a good proxy for the actual ability to locate the crime in a real case scenario, the figure presents evidence that users often misinterpret geospatial information when it is presented as unstructured text (e.g., address, building name). This miscalculation would make it less likely for them to comply successfully (i.e., avoiding a dangerous area). It follows that in a lab setting participants' willingness to comply may largely overestimate the performance of the system in-use. Future assessment of EUT should consider this gap between situational awareness and performance, studying how to enhance representational fidelity not just in terms of accuracy (i.e., the location is correct), but also meaningfulness (i.e., users recognize the location). Future work should also be devoted to the development of measures that enable system-in-use evaluation and investigate ways to increase representational fidelity in terms of the participants' ability to locate the threat and increase their geospatial awareness. Existing solutions for possibly improving spatial situational awareness may be as simple as embedding a URL call to Google API in the SMS to pop up on any internet browser the recipient's position relative to the threat. The reason why similar solutions have not been adopted yet could be mostly theoretical. Since EAS are used during crises, it is critical to be able to produce realistic simulations of their in-use performance, as it is difficult to evaluate them during actual deployment.

4.10 Conclusion

This research proposes a representation theory perspective for studying the effective use of an EAS. Prior literature calls this approach EUT, and we extend EUT by assessing the theory in the context of emergency communication. Since this context presents severe time constraints, we reconceptualized and measured the constructs of EUT to account for their time-dependent nature. Adopting the EUT lenses means to study the effective use and the performance of an EAS *in-use*. While focusing on the system in-use may sound intuitive, we show that, currently, the focus is on measuring the system before use (i.e., its qualities). We explained that the focus on EAS qualities is probably due to socio-political reasons, and scrutinized two events that influenced the

EAS implementation strategy: the 1990 Clery Act, and the 2007 Virginia Shooting.

The merit of EUT is to offer a perspective for studying the effective use of the system-in-use. We assessed the validity of the construct of effective use in an emergency context and supported the positive relationship between effective use and performance. Therefore, we extended the theory by contextualizing the original formulation of EUT in the emergency context. Our contextualization of EUT in a chaotic environment, we contributed the first measure of EUT's dimensions in the emergency context. The results support the conceptualization of effective use as a time-dependent and tri-dimensional construct, consisting of transparent interaction, representational fidelity, and situational awareness. They also support that effective use increases users' willingness to comply with alert messages.

Appendices

APPENDIX A
SUPPLEMENTARY MATERIAL CHAPTER 2

A.1 Methodology for identifying research publications

In selecting articles we pursued a "good or reasonable coverage" (Rowe, 2014, p. 246) following two criteria: (a) identifying manuscripts showing a high-level of theoretical understanding in IS, (b) foresee emergent research trends in EMIS. For *a*, we retain articles from the "Basket of Eight" (14), assuming those outlets portray most rigorous theoretical understanding of emergency management in the IS community. For *b*, we consider full-research articles from relevant conferences: ICIS (8) and its regional chapters ECIS, (6), AMCIS (18), PACIS (14). We decide to include conference articles to help anticipate emerging trends in EMIS scholarship. We limited the search only to articles published within the last ten years (2008-2018), which is a common time-frame (Rowe, 2014, p. 247). We searched both the AIS e-Library and each outlets' websites using the keywords: crisis, emergency, catastrophe, disaster, humanitarian disaster, natural disaster, disaster management. From the results, we excluded articles which investigate company organizational crises, which are not disaster-related (e.g., company's reputational threats, financial crises), or articles that specifically analyze business continuity planning (e.g., (Baham, Calderon, & Hirschheim, 2017; Park, Sharman, & Rao, 2015)). Once we identified a relevant article, we screened its references' section to identify other articles that comply with our criteria.

We retained 69 publications: 14 journal articles and 55 conference proceedings. The number of journal articles retained is in line with prior literature reviews on EMIS. For instance, (Michael A Erskine & Pepper, 2016) found six articles in the Bo8 in the decade 2003-2013. Moreover, we followed up both through online database and personally emailing the authors of conference articles to include conference proceedings which developed into journal articles outside the Basket-of-Eight. That lead to include: (Tapia, Tchouakeu, Maldonado, & Maitland, 2013; Gill et al., 2015; Haghighi, Burstein, Zaslavsky, & Arbon, 2013; Kaewkitipong, Chen, & Ractham, 2016; Othman, Ahmad, Suliman, Arshad, & Maidin, 2014; Michael A Erskine & Pepper, 2016; Hans Jochen Scholl & Patin, 2014; Valecha, 2019; McNab et al., 2011; F. Cheong & Cheong, 2013). The ratio-

nale for this additional step is to give an account of IS research that develops in the IS community but does access top-tier IS journals. We are aware that our research ignores many IS and non-IS outlet that publish emergency management research. In May 2019, the version 1.5 of "The Disaster Information Reference Library" (http://faculty.washington.edu/jscholl/dirl/index.php) contains 2,533 references. A manual approach to theory landscaping on such an amount of manuscripts seems unfeasible for small reserach groups. Thus, we stress that a complete theoretical review of the emergency management (Par, Tate, Johnstone, and Kitsiou, 2016, p. 500 calls *saturation*) is beyond the scope of this research.

A.1.1 Literature Coding

To guide the understanding of the scholarly discourse in EMIS we coded the manuscripts following the matrix in Table A.1). We started with the goal of categorizing articles by their theoretical framework. However, other relevant trends surfaced while proressing in our understanding of the literature. For instance, the recurrent use of certain domains of investigation (i.e., social media analysis), or the use of specific constructs (i.e., *situational awareness*). Therefore, the coding process was iterative, leading us to re-read articles to look for patterns that we may have initially ignored. We coded the references according to the variables of interest, revising the initial coding backwards as we run into cross-citations between our manuscripts in the coding matrix. The process stretched over several month which allowed the authors to take a critical look at their initial coding, comparing initial coding decisions to those of the authors' future-self, in contrast with other approaches that pursue inter-coder reliability (Recker et al., 2019).

A.1.2 Coding methodology

To code each article's theoretical lenses, we match an article to a theoretical framework whenever the authors claim to build on a major seminal theory or refer to a seminal article. While "references are not theory" (Sutton & Staw, 1995, p. 372), we considered references as signaling that the research gravitates around the a certain theoretical perspective, yet without necessarily contributing to theory development or testing. Since they also contribute to shape a theoretical discourse, we code them to give an account of which theoretical perspectives are attracting scholarly interest in EMIS.

Author	Theory name and type	SA	SM	Publication	Disaster
(Adrot and Pallud 2009)	Review Article (1)			AMCIS	General Crisis
(Adrot and Robey 2008)	Organizational Coordination under Improvisation (1)			AMCIS	General Crisis
(Chen et al. 2008)	Situational Crisis Comm. Theory (1)	X	Twitter	AMCIS	General Crisis
(Erskine et al. 2013)	- (1)			AMCIS	General Crisis
(Gill et al. 2014)	Gill Framework (1)		Twitter	AMCIS	Fire
(Han et al. 2011)	Theory of Compliance (2)			AMCIS	Shooting
(Horita et al. 2014)	Resource Meta-Model (1)			AMCIS	Flood
(Pepper and Erskine 2014)	- (1)			AMCIS	General Crisis
(Plotnick et al. 2009)	- (1)		Multiple	AMCIS	General Crisis
(Sackmann et al. 2013)	- (3)			AMCIS	General Crisis
(Scholl and Patin 2012)	- (1)			AMCIS	General Crisis
(Sebastian and Bui 2009)	Information Theory (4)	X		AMCIS	General Crisis
(Shan et al. 2017)	- (1)		Multiple	AMCIS	General Crisis
(Son et al. 2017)	Information Theory (4)		Twitter	AMCIS	Flood
(Tapia et al. 2010)	Multi Organizational Governance Theory (2)			AMCIS	General Crisis
(Taylor and Arthanari 2018)	- (1)			AMCIS	General Crisis
(Valecha et al. 2012)	Collaboration Theories (2)	X		AMCIS	Plane Crash
(Xu et al. 2017)	Situational Crisis Communication Theory (1)		Twitter	AMCIS	General Crisis
(Allen et al. 2013)	Activity Theory (2)			Basket of 8	General Crisis
(Chen et al. 2008)	Activity Theory (2)	X		Basket of 8	General Crisis
(Chen et al. 2013)	Activity Theory (2)			Basket of 8	Fire
(Day et al. 2009)	Information Flow (2)			Basket of 8	Hurricane
(Han et al. 2015)	Theory of Compliance (2)			Basket of 8	Shooting
(Leidner et al. 2009)	Resource Based View (2)			Basket of 8	General Crisis
(Leong et al. 2015)	Social Action (2)		Multiple	Basket of 8	Flood
(Oh et al. 2013)	Rumor Theory (2)			Basket of 8	General Crisis
(Oh et al. 2015)	Collective Behavior (2)		Twitter	Basket of 8	Conflict
(Pan et al. 2012)	Information Flow (3)		Multiple	Basket of 8	General Crisis
(Tim et al. 2017)	Affordance (2)	X	Multiple	Basket of 8	Flood
(Vaast et al. 2017)	Affordance (2)		Twitter	Basket of 8	Oil Spill
(Valecha et al. 2019)	Activity Theory (2)			Basket of 8	General Crisis
(Yang et al. 2012)	Situation Awarness oriented design (5)	X		Basket of 8	Public Safety
(Eismann et al. 2016)	Collective Behavior (2)			ECIS	General Crisis

Author	Theory name and type	SA	SM	Publication	Disaster
(Fischer et al. 2016)	Communication Barriers (1)			ECIS	General Crisis
(Mirbabaie and Zapatka 2017)	Information sharing (3)		Twitter	ECIS	Terrorist Attack
(Reuter et al. 2017)	Media Richness Theory (2)		Multiple	ECIS	General Crisis
(Stieglitz et al. 2018)	Technology-Organization-Environment (2)		Multiple	ECIS	General Crisis
(van Gorp et al. 2015)	Affordance (2)		Facebook	ECIS	Flood
(Chen et al. 2008)	Activity Theory (2)	X		ICIS	Fire
(Han et al. 2011)	Theory of reasonable action (2)			ICIS	Shooting
(Kaewkitipong et al. 2012)	Structuration Theory (2)		Multiple	ICIS	Flood
(Kwon et al. 2011)	Gatekeeping (2)		Twitter	ICIS	Conflict
(McNab et al. 2009)	Cue-summation Theory (2)			ICIS	General Crisis
(Neville et al. 2018)	Design Science (5)	X		ICIS	General Crisis
(Oh et al. 2010)	Rumor Theory (2)		Twitter	ICIS	Earthquake
(Sakurai and Kokuryo 2014)	Frugal IS (1)			ICIS	Earthquake
(Bunker and Smith 2009)	Collaboration Theories (2)			PACIS	Flood
(Cheong and Cheong 2011)	- (3)	X	Twitter	PACIS	Flood
(Haghighi et al. 2013)	Mass Gathering (5)		Twitter	PACIS	General Crisis
(Inan Beydoun 2017)	Agent-based modelling (2)			PACIS	General Crisis
(Lestari et al. 2016)	- (5)			PACIS	Fire
(Li et al. 2014)	Rumor Theory (2)		Twitter	PACIS	Earthquake
(Liu et al. 2014)	Rumor Theory (2)		Twitter	PACIS	Tornado
(Mousavi et al. 2012)	Collaboration Theories (2)			PACIS	General Crisis
(Mukkamala and Beck 2016)	- (1)	X	Twitter	PACIS	Hurricane
(Mukkamala and Beck 2017)	Social Presence (2)		Twitter	PACIS	Flood
(Othman et al. 2013)	COBIT 5 (1)			PACIS	Flood
(Ping et al. 2011)	Contingency Theory (2)			PACIS	General Crisis
(Rodzi et al. 2017)	Knowledge Integration Model (2)			PACIS	General Crisis
(Sabou and Klein 2016)	Collaboration Theories (2)			PACIS	Earthquake
(Cheong and Cheong 2013)	- (3)		Twitter	Journal	Flood
(Erskine et al. 2016)	- (1)			Journal	General Crisis
(Gill et al. 2014)	Gill Framework (1)		Twitter	Journal	Fire
(Haghighi et al. 2013)	Mass Gathering (1)		Twitter	Journal	General Crisis
(Kaewkitipong et al. 2016)	Structuration Theory (2)		Multiple	Journal	Flood
(McNab et al. 2011)	Cue-summation Theory (2)			Journal	General Crisis

Author	Theory name and type	SA	SM	Publication	Disaster
(Othman et al. 2014)	COBIT 5 (1)			Journal	Flood
(Scholl and Patin 2014)	- (1)			Journal	General Crisis
(Tapia et al. 2013)	Multi Organizational Governance Theory (2)			Journal	General Crisis

Table A.1: *SA*: Situational Awareness; *SM*: Social Media *Disaster*: type of disaster studied

A.2 Research Questions

Table A.2: Research questions in EMIS articles.

Article	Research question
(Allen et al., 2014)	Emergency responders' information communicating and sharing and the influence of organizational rules and norms on information sharing and interoperability
(Chen, Raj Sharman, et al., 2008)	1. What is an effective data modeling approach for emergency standard development? 2. What are the key information components and their internal structures for emergency management interoperability?
(Chen, Sharman, Rao, & Upadhyaya, 2013; Chen, Sharman, Rao, & Upadhyaya, 2008)	Object-oriented data model that supports real-time response information exchange during fire incidents response
(Day, Junglas, & Silva, 2009)	Information flows in the management of the disaster relief supply chains that formed following Hurricane Katrina
(Han et al., 2015; Han, Ada, Sharman, Rao, & Brennan, 2011; Han, Sharman, Brennan, Rao, et al., 2011)	1. What are the important factors influencing students' ENS-message compliance intentions? 2. How does the level of trust in the quality of information affect compliance intention when the information is received? 3. Does the importance of these factors change in different types of incidents? 4. What we can do to improve immediate compliance?
(Leong et al., 2015)	How does social media empower the community in crisis response?
(Leidner, Pan, & Pan, 2009)	What IS resources (assets and capabilities) are valuable in crisis response situations?
(Oh et al., 2013; Oh et al., 2010)	Under what conditions does collective social reporting function as a community intelligence mechanism to address crisis problems? Under what conditions does social reporting degenerate into a rumor-mill?
(Oh et al., 2015)	1. What is the collective sense-making process developed over time during the 2011 Egypt Revolution? 2. What are the characteristics of Twitter hashtags that influenced the collective sense-making process during the 2011 Egypt Revolution?
(Pan et al., 2012)	What is the role of IT in information networks?
(Tim et al., 2017)	How does social media enable disaster response?
(Valecha et al., 2019; Valecha et al., 2012)	A conceptual modeling grammar to help communities of responders to share their expertise
(Vaast et al., 2017)	How does social media use afford connective action?
(Yang et al., 2012)	The use of an emergency response information platform before and during an incident

Table A.3: Research questions in EMIS articles outside the Basked-of-Eight journals.

Article	Research question
(T. X. Bui & Sebastian, 2011; Sebastian & Bui, 2009) (F. Cheong & Cheong, 2013, 2011)	What kind of information we should provide to volunteers to help them help others?
(Michael A Erskine & Pepper, 2016; Michael A. Erskine, Christopher, & Hossein, 2013)	Can a mobile expert system: 1. effectively guide witnesses or victims of an emergency incident? 2. improve emergency reporting to be more efficient than by placing a voice telephone call? 3. Can responses to essential questions be collected optimally allowing emergency dispatchers to make better-informed decisions and allocate resources more effectively?
(Gill, Alam, & Eustace, 2015, 2014)	How to best identify and assess different social media concerns to effectively establish a social media-enabled disaster information management environment for the timely sourcing and distribution of disaster information?
(Haghighi, Burstein, Zaslavsky, & Arbon, 2013; Haghighi, Burstein, Li, & Wang, 2013)	How can a domain ontology improve decision making in the field of medical emergency management by providing a unified and common knowledge base for intelligent decision support?
(Kaewkitipong, Chen, & Ractham, 2016; Kaewkitipong, Chen, & Ractham, 2012)	1. How can social media be used for knowledge sharing among different stakeholders throughout the crisis cycle? 2. How does social media change the social structure among stakeholders throughout the crisis cycle?
(McNab, Hess, & Valacich, 2011, 2009)	How to improve the understanding of early information processing and selection performance in emergency response systems?
(Othman, Ahmad, Suliman, Arshad, & Maidin, 2014; Othman, Ahmad, Suliman, & Arshad, 2013)	How does collaborating agencies involved in the flood management in Malaysia govern and manage their data, information, and knowledge to enable decision making in alleviating the problem in a flood disaster?
(Hans Jochen Scholl & Patin, 2014; Hans J Scholl, Patin, & Chatfield, 2012)	1. What is the role of the impacted information infrastructure used for response and recovery? 2. What are the specific vulnerabilities of an information infrastructure? 3. What makes an information infrastructure resilient?
(Tapia, Tchouakeu, Maldonado, & Maitland, 2013, 2010)	What are the drivers of cross-organizational collaboration among large, international humanitarian organizations?

A.3 Definitions

There is a variety of uses of pivotal constructs in the EMIS literature that may lead to *construct identity fallacy* "wherein a construct pair references the same or different phenomena and are given dissimilar or identical names, respectively" (Larsen & Bong, 2016, p. 530). Synonyms (different names for the same construct) and homonyms (same names for different constructs) hinder the enclosure of the relevant literature and the development of new theory. In some of the articles we reviewed, the authors loosely define common constructs in EMIS, or rely on their common dictionary definition. Table A.3 presents an overview of synonyms and homonyms within our literature review. Therefore, we recombined existing definitions from our corpus of manuscripts into consolidated construct definitions.

Table A.4: Table of definitions

Situational Awareness
"the decision-makers' moment-by-moment ability to monitor and understand the state of a complex system and its environment (Biros et al. 2004)" (Chen, Raj Sharman, Raghav, & Shambhu J, 2008) "Situational awareness refers to the way human beings extract meaning from information about their surroundings to develop mental models of a situation by integrating the extracted information with their own knowledge to explore and anticipate further action (Seebach et al. 2011;Vidulich et al. 1994)" (Mukkamala & Beck, 2016) "provides an understanding of the environment as a basis for efficient decision-making. It consists of three levels of the cognitive process, namely perception, comprehension, and projection." (Valecha, Sharman, Rao, & Upadhyaya, 2012, p. 2) "awareness of what is happening around you and understanding what that information means to you now and in the near future" (Yang, Su, & Yuan, 2012, p. 766)
Disaster
"A disaster is a sudden event that seriously affects the normal routine conditions of a community or society." (Mukkamala & Beck, 2016, p. 1380) "A disaster or emergency is a situation which is threatening a large number of people and/or important economic/ecological infrastructures and requires shared resources, information, and communication of more than one organization or authority to prevent and mitigate its impact" (Vogt, Hertweck, & Hales, 2011, p. 2). "A disaster indicates an unpredictable, uncertain and urgent event that imposes severe threats to life, well-being or other significantly held values" (Leidner, Pan, & Pan, 2009) "A disaster is a large-scale emergency that seriously disrupts "normal" activities in the affected area" (Gonzalez, Labaka, Hiltz, & Turoff, 2016, p. 152) "Is an 'unexpected' unpracticed and unprogrammable' (McKinney, 2009, p. 42) event, which often presents 'entirely new environmental, geographical, political, economic and sociological concerns" (Yates & Paquette, 2011, p. 7)
Crisis
Event characterized by "non-trivial threats to life, well-being, or other significantly held values, by unpredictability, and by urgency" (Leidner, Pan, & Pan, 2009, p. 80)
Emergency
Emergency response is "the process of gathering resources and acting upon the problems immediately during and after a critical incident" (Chen, Raj Sharman, Raghav, & Shambhu J, 2008, p. 1)

APPENDIX B
SUPPLEMENTARY MATERIAL CHAPTER 3

B.1 Ranking

This section presents the channels' preferences for on-campus emergency communication. We asked our sample ($N = 393$) to rank which channel they would most likely read first if an emergency message were sent. Table B.1 shows that, on average, email has been on ranked 1.80 on a 1 to 5 scale. We fitted a Weighted Distance-Based Model with Kendalls Tau distance to assess the agreement in ranking channels at their mean value. Higher coefficients indicate agreement about ranking a channel at its mean rank. The results suggest that students prefer SMS and email for receiving timely warnings.

Table B.1: Favourite channel for receiving emergency messages

	channel	avg	b	se
1	email	1.71	0.81	0.06
2	SMS	2.22	0.85	0.08
3	social media	3.13	0.60	0.08
4	uni website	3.25	1.68	0.11
5	uni social media	4.70	1.19	0.11

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